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A CBO STUDY

Policy Options for Reducing CO_2 Emissions

February 2008

The Congress of the United States ■ Congressional Budget Office

Preface

There is a growing scientific consensus that rising concentrations of carbon dioxide (CO_2) and other greenhouse gases, which result from the burning of fossil fuels, are gradually warming the Earth's climate. The amount of damage associated with that warming remains uncertain, but there is some risk that it could be large and perhaps even catastrophic. Reducing that risk would require restraining the growth of CO_2 emissions—and ultimately limiting those emissions to a level that would stabilize atmospheric concentrations—which would involve costs that are also uncertain but could be substantial.

The most efficient approaches to reducing emissions of CO_2 involve giving businesses and households an economic incentive for such reductions. Such an incentive could be provided in various ways, including a tax on emissions, a cap on the total annual level of emissions combined with a system of tradable emission allowances, or a modified cap-and-trade program that includes features to constrain the cost of emission reductions that would be undertaken in an effort to meet the cap. This Congressional Budget Office (CBO) study—prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources—compares those policy options on the basis of three key criteria: their potential to reduce emissions efficiently, to be implemented with relatively low administrative costs, and to create incentives for emission reductions that are consistent with incentives in other countries. In keeping with CBO's mandate to provide objective, impartial analysis, the report contains no recommendations.

The study was written by Terry Dinan of CBO's Microeconomic Studies Division under the guidance of Joseph Kile and David Moore. Robert Dennis, Douglas Hamilton, Robert Shackleton, and Thomas Woodward provided comments. Outside CBO, William Pizer of Resources for the Future, Reid Harvey of the Environmental Protection Agency, and Martin Weitzman of Harvard University provided comments. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Christine Bogusz and Christian Howlett edited the study, Sherry Snyder proofread it, and Angela McCollough prepared the final draft of the manuscript. Maureen Costantino prepared the study for publication, designed the cover, and took the photograph of the traffic on the cover. Lenny Skutnik printed copies of the study, Linda Schimmel handled the distribution, and Simone Thomas prepared the electronic version for CBO's Web site (www.cbo.gov).

Peter R. Orszag
Director

February 2008

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Summary

Global climate change is one of the nation's most significant long-term policy challenges. Human activities are producing increasingly large quantities of greenhouse gases, particularly carbon dioxide (CO_2), which accumulate in the atmosphere and create costly changes in regional climates throughout the world. The magnitude of such damage remains highly uncertain, but there is growing recognition that some degree of risk exists for the damage to be large and perhaps even catastrophic. Reducing greenhouse-gas emissions would be beneficial in limiting the degree of damage associated with climate change. However, decreasing those emissions would also impose costs on the economy—in the case of CO_2, because much economic activity is based on fossil fuels, which release carbon in the form of carbon dioxide when they are burned. Most analyses suggest that a carefully designed program to begin lowering CO_2 emissions would produce greater benefits than costs.

The most efficient approaches to reducing emissions involve giving businesses and individuals an incentive to curb activities that produce CO_2 emissions, rather than adopting a "command and control" approach in which the government would mandate how much individual entities could emit or what technologies they should use. Incentive-based policies include a tax on emissions, a cap on the total annual level of emissions combined with a system of tradable emission allowances, and a modified cap-and-trade program that includes features to constrain the cost of emission reductions that would be undertaken in an effort to meet the cap. In this study, the Congressional Budget Office (CBO) compares these incentive-based approaches, focusing on three key criteria:

- Efficiency in maintaining a balance between the uncertain benefits and costs of reducing CO_2 emissions,
- Ease or difficulty of implementation, and
- Possible interactions with other countries' policies for curbing CO_2—that is, the potential to ensure that U.S. and foreign policies produce similar incentives to cut emissions inside and outside the United States.

Other criteria could be of interest to policymakers in determining how best to address concerns about climate change. For example, the efficiency criterion addresses how well policies might function to minimize the cost of reducing emissions over a period of several decades; however, policymakers may choose to place more emphasis on providing certainty about the amount of emissions at specific points in time. Similarly, policymakers may also wish to focus on how different policy designs affect different segments of society.

Policy Options for Reducing Emissions

Incentive-based approaches can reduce emissions at a lower cost than more restrictive command-and-control approaches because they provide more flexibility about where and how emission reductions are achieved.

Under a tax, policymakers would levy a fee for each ton of CO_2 emitted or for each ton of carbon contained in fossil fuels. The tax would motivate entities to cut back on their emissions if the cost of doing so was less than the cost of paying the tax. As a result, the tax would place an upper limit on the cost of reducing emissions, but the total amount of CO_2 that would be emitted in any given year would be uncertain.

In contrast, under a cap-and-trade program, policymakers would set a limit on total emissions during some period and would require regulated entities to hold rights, or allowances, to the emissions permitted under that cap. (Each allowance would entitle companies to emit one ton of CO_2 or to have one ton of carbon in the fuel that they sold.) After the allowances for a given period were distributed, entities would be free to buy and

sell the allowances among themselves. Unlike a tax, a cap-and-trade program would place an upper limit on the amount of emissions, but the cost of reducing emissions would vary on the basis of fluctuations in energy markets, the weather (for example, an exceptionally cold winter would increase the demand for energy and make meeting a cap more expensive), and the technologies available for reducing emissions.

Given the gradual nature of climate change, the uncertainty that exists about the cost of reducing emissions, and the potential variability of the cost of meeting a particular cap on emissions at different points in time, a tax could offer significant advantages. If policymakers chose to specify a long-term target for cutting emissions, a tax could be set at a rate that could meet that target at a lower cost than a comparable cap. In addition, if policymakers set the tax rate at a level that reflected the expected benefits of reducing a ton of emissions (which would rise over time), a tax would keep the costs of emission reductions in balance with the anticipated benefits, whereas a cap would not.

There is significant interest, however, in a cap-and-trade approach (which has been used in the United States to reduce emissions that cause acid rain and is currently being used in the European Union to limit CO_2 emissions).[1] This study therefore explores ways in which policymakers could preserve the structure of a cap-and-trade program but achieve some of the efficiency advantages of a tax. Specifically, policymakers could take one or more of these steps:

- Set a ceiling—typically referred to as a safety valve—or a floor on the price of emission allowances. The government could maintain a ceiling by selling companies as many allowances as they would like to buy at the safety-valve price. The government could maintain a price floor by selling a significant fraction of allowances in an auction and specifying a reserve price.

- Permit firms to transfer emission-reduction requirements across time—by "banking" allowances in one year for use in future years or by "borrowing" future allowances for use in an earlier year. Firms would have an incentive to bank allowances when the cost of cutting emissions was low (relative to anticipated future costs) and to borrow allowances when costs were high.

- Modify the stringency of the cap from year to year on the basis of the price of allowances. Policymakers could loosen the cap if the price of allowances rose too high, or they could tighten the cap if the price fell too low. Some analysts have suggested the use of a "circuit breaker" that would halt the gradual tightening of the cap if the price of allowances exceeded a specified trigger price. The cap would resume its decline if the price of allowances eventually fell below the trigger price. Loosening or tightening the cap could be achieved indirectly by altering conditions under which firms could bank or borrow allowances.

1. For more information about U.S. cap-and-trade programs for sulfur dioxide and nitrous oxide and about the European Union's program for carbon dioxide, see the appendix.

Results of CBO's Analysis

The policy options described above differ in their potential to reduce emissions efficiently, to be implemented with relatively low administrative costs, and to create incentives for emission reductions that are consistent with incentives in other countries. CBO draws the following conclusions:

- A tax on emissions would be the most efficient incentive-based option for reducing emissions and could be relatively easy to implement. If it was coordinated among major emitting countries, it would help minimize the cost of achieving a global target for emissions by providing consistent incentives for reducing emissions around the world. If other major nations used cap-and-trade programs rather than taxes on emissions, a U.S. tax could still provide roughly comparable incentives for emission reductions if the tax rate each year was set to equal the expected price of allowances under those programs. (See Summary Table 1 for a qualitative comparison of selected policies.)

- An inflexible annual cap (one whose level was not affected by the price of emission allowances and under which firms would not be allowed to bank or borrow allowances) would be the least efficient option among those considered here, although it could be relatively easy to implement, depending on key design features. Linking the cap-and-trade programs of various countries could create significant concerns, however: Nations would give up sovereignty over the price of the allowances traded in their programs and the extent

to which emissions were reduced in ways that met their programs' criteria.

- A cap-and-trade program that included a price ceiling (safety valve) and either a price floor or banking provisions could be significantly more efficient than an inflexible cap, although somewhat less efficient than a tax. It might also be relatively easy to implement, depending on specific design decisions. If major emitting countries agreed to establish such programs—and to set their safety valves at roughly the same level—they could create similar incentives to reduce emissions without formally linking their cap-and-trade programs. Alternatively, if other developed countries taxed CO_2 emissions, a safety valve in a U.S. cap-and-trade program could be set at a level consistent with that tax.

- Moderating the price of allowances by altering the stringency of a cap—or the extent to which firms could use banked and borrowed allowances—would be considerably more difficult to implement than setting a price floor or ceiling directly. Price volatility in the allowance market could make it difficult for policymakers to know when to alter the supply of allowances and would mean that no particular price outcome could be guaranteed. One particular form of price-sensitive cap—a cap-and-trade program with a circuit breaker—could be more efficient than an inflexible cap. However, such a program would be less efficient than the other policy options that CBO examined.

Comparison of Policies' Efficiency

The most efficient policy tool for decreasing CO_2 emissions is the one that can best balance the costs and benefits of the reductions, even when both are uncertain. The features that make a policy tool most efficient would also enable it to minimize the cost of achieving a given target, even if that target was not explicitly chosen to balance costs and benefits.

A Tax Versus an Inflexible Cap. Analysts generally conclude that a tax would be a more efficient method of reducing CO_2 emissions than an inflexible cap. The efficiency advantage of a tax stems from the contrast between the long-term cumulative nature of climate change and the short-term sensitivity of the cost of emission reductions. Climate change results from the buildup of CO_2 in the atmosphere over several decades; emissions in any given year are only a small portion of that total. As a result, limiting climate change would require making substantial reductions in those emissions over many years, but ensuring that any *particular limit* was met in any *particular year* would result in little, if any, additional benefit (avoided damage). In contrast, the cost of cutting emissions by a particular amount in a given year could vary significantly depending on a host of factors, including the weather, disruptions in energy markets, the level of economic activity, and the availability of new low-carbon technologies (such as improvements in wind-power technology).

Relative to a cap-and-trade program with prespecified emission limits each year, a steadily rising tax could better accommodate cost fluctuations while simultaneously achieving a long-term target for emissions. Such a tax would provide firms with an incentive to undertake more emission reductions when the cost of doing so was relatively low and allow them to reduce emissions less when the cost of doing so was particularly high. In contrast, an inflexible cap-and-trade program would require that annual caps were met regardless of the cost, thereby failing to take advantage of low-cost opportunities to cut more emissions than were required by the cap and failing to provide firms with leeway in years when costs were higher.

The efficiency advantage of a tax over an inflexible cap depends on how likely it is that actual costs will differ from what policymakers anticipated when they set the level of the cap. Given the uncertainties involved, such differences are likely to be large—and, therefore, analysts generally conclude that the efficiency advantage of a tax is likely to be quite large. Specifically, available research suggests that in the near term, the net benefits (benefits minus costs) of a tax could be roughly five times greater than the net benefits of an inflexible cap.[2] Put another way, a given long-term emission-reduction target could be met by a tax at a fraction of the cost of an inflexible cap-and-trade program.

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2. See, for example, William A. Pizer, "Combining Price and Quantity Controls to Mitigate Global Climate Change," *Journal of Public Economics,* vol. 85 (2002), pp. 409–434; Michael Hoel and Larry Karp, "Taxes and Quotas for a Stock Pollutant with Multiplicative Uncertainty," *Journal of Public Economics,* vol. 82 (2001), pp. 91–114; and Richard G. Newell and William A. Pizer, "Regulating Stock Externalities Under Uncertainty," *Journal of Environmental Economics and Management,* vol. 45 (2002), pp. 416–432.

Summary Table 1.

Comparison of Selected Policies for Cutting CO_2 Emissions

Policy	Efficiency: Ranking	Efficiency: Considerations	Implementation Considerations	International Consistency Considerations
Carbon Dioxide Tax	1	A tax would avoid significant year-to-year fluctuations in costs. Setting the tax equal to the estimate of the marginal benefit of emission reductions would motivate reductions that cost less than their anticipated benefits but would not require reductions that cost more than those benefits. Research indicates that the net benefits of a tax could be roughly five times as high as the net benefits of an inflexible cap. Alternatively, a tax could achieve a long-term target at a fraction of the cost of an inflexible cap.	An upstream tax would not require monitoring emissions and could be relatively easy to implement. It could build on the administrative infrastructure for existing taxes, such as excise taxes on coal and petroleum.	A U.S. tax could be set at a rate consistent with carbon dioxide taxes in other countries. Consistency would require comparable verification and enforcement. If countries imposed taxes at different points in the carbon supply chain, special provisions could be needed to avoid double-taxing or exempting certain goods. Setting a U.S. tax that would be consistent with allowance prices under other countries' cap-and-trade systems would be somewhat more difficult because it would require predicting allowance prices in different countries.
Cap With Safety Valve and Either Banking or a Price Floor	2	A cap-and-trade program that included a safety valve and either banking or a price floor could have many of the efficiency advantages of a tax. The safety valve would prevent price spikes and could keep the costs of emission reductions from exceeding their expected benefits. Banking would help prevent the price of allowances from falling too low, provided that prices were expected to be higher in the future. A price floor, however, would be more effective at keeping the cost of emission reductions from falling below a target level.	An upstream cap would not require monitoring emissions. It would require a new administrative infrastructure to track allowance holdings and transfers. Implementing a safety valve would be straightforward: The government would offer an unlimited number of allowances at the safety-valve price. Banking has been successfully implemented in the U.S. Acid Rain Program. A price floor would be straightforward to implement only if the government chose to sell a significant fraction of emission allowances in an auction.	Either a safety valve or banking would become available to all sources of CO_2 emissions in a linked international cap-and-trade program. Some countries could object to linking with a U.S. program that included those features, because linked countries could not ensure that their emissions would be below a required level in a given year. Linking would also create concerns about inconsistent monitoring and enforcement among countries and international capital flows (as described below in the inflexible cap policy). Countries with different cap-and-trade programs could capture many of the efficiency gains that would be achieved by linking—while avoiding some of the complications—if they each included banking (or set a similar price floor) and agreed on a safety-valve price.

Continued

Summary Table 1.

Continued

Policy	Efficiency		Implementation Considerations	International Consistency Considerations
	Ranking	Considerations		
Cap With Banking and Either a Circuit Breaker or Managed Borrowing	3	Allowing firms to bank allowances would help prevent the price of allowances from falling too low, provided that prices were expected to be higher in the future. Including a circuit breaker—or increasing the ability of firms to borrow allowances—would help keep the price of allowances from climbing higher than desired, but would be significantly less effective at doing so than a price ceiling.	An upstream cap would not require monitoring emissions. It would require a new administrative infrastructure to track allowance holdings and transfers. Banking has been successfully implemented in the U.S. Acid Rain Program. Determining when to trigger a circuit breaker, or modify borrowing restrictions, would require judgment about current and future allowance prices. Such interventions could aggravate price fluctuations if those judgments were incorrect.	Including banking and either a circuit breaker or borrowing in the U.S. program could reduce the likelihood of linking because it would cause uncertainty about the stringency of the U.S. cap relative to other countries' caps and about the total supply of allowances in the global trading market.
Inflexible Cap	4	Allowance prices could be volatile. An inflexible cap could require too many emission reductions (relative to their benefits) if the cost of achieving them was higher than anticipated and could require too few reductions if the cost of meeting the cap was lower than policymakers had anticipated.	An upstream cap would not require monitoring emissions. It would require a new administrative infrastructure to track allowance holdings and transfers.	Linking an inflexible U.S. cap with other countries' cap-and-trade systems would create a consistent global incentive for reducing emissions. However, inconsistent monitoring and enforcement in any one country could undermine the entire linked trading system. Further, linking would alter allowance prices in participating countries, create capital flows between countries, and possibly encourage countries to set their caps so as to influence those flows.

Source: Congressional Budget Office.

Note: An "upstream" tax or cap would be imposed on suppliers of fossil fuel on the basis of the carbon dioxide (CO_2) emitted when the fuel was burned. A "safety valve" would set a ceiling on the price of allowances. "Banking" would allow firms to exceed their required emission reductions in one year and use their extra allowances in a later year. Under a "circuit breaker," the government would stop a declining cap from becoming more stringent if the price of allownces exceeded a specified level.

Flexible Cap Approaches. A cap-and-trade program could incorporate various design features that would keep allowance prices from rising or falling farther than policymakers wanted. Combined, some of those features could allow a cap-and-trade program to achieve many of the efficiency advantages of a tax on emissions.

Keeping Costs From Climbing Too High. Including a safety valve could make a cap-and-trade program more efficient than an inflexible cap. Such a policy would set a ceiling on the price of allowances, preventing the cost of reducing emissions from exceeding either the best available estimate of the benefit (avoided damage) that would result from those reductions or the cost that policymakers consider acceptable.

Alternatively, policymakers could attempt to cap the price of allowances by adjusting the stringency of the cap. For example, policymakers could specify a circuit breaker, which would prevent a declining cap from becoming more stringent (fixing the cap at one level) if the price of allowances reached a certain level. Unlike a safety valve, a circuit breaker would not necessarily stop the price of allowances from continuing to rise, but it would result in smaller price increases than would otherwise occur. (The price would probably still increase because meeting a fixed cap would become more and more costly over time as the economy grew.)

Finally, allowing companies to borrow allowances—and thus defer emission reductions to the future—could help keep the price of allowances from rising too high. Policymakers could alter the constraints placed on firms' use of borrowed allowances on the basis of the price of allowances. Like a circuit breaker, such an approach could help constrain the price of allowances under some circumstances, but it is unlikely to be as effective at doing so as a safety valve. Policymakers would need to forecast future allowance prices in order to know when to loosen or tighten constraints on borrowing. To the extent that those forecasts were inaccurate, borrowing could exacerbate price fluctuations. Further, firms would find it profitable to borrow future allowances only if they expected the price of allowances to be lower in the future. That is, borrowing could help deal with temporary spikes in allowance prices but not circumstances in which allowance prices were expected to remain high in the long term.

Keeping Costs From Falling Too Low. Policymakers could prevent the price of allowances from falling too low by setting a price floor. If the government chose to sell a significant portion of the allowances by auction, it could specify a reserve price and withhold allowances from the auction as needed to maintain that price. Attempting to prevent the price of allowances from dropping too low by adjusting the supply of allowances would entail the same complications associated with a circuit breaker.

Alternatively, policymakers could help keep the price of allowances from falling below some desired level by allowing companies to exceed their required emission reductions in low-cost years in order to bank allowances for use in future high-cost years. The additional emission reductions motivated by banking in low-cost years would put upward pressure on the price of allowances in those years. Similarly to borrowing, banking would be most effective in addressing short-term lows in allowance prices rather than circumstances in which allowance prices were expected to remain low in the long term.

Comparison of Policies' Implementation

Policies that are efficient in theory will be efficient in practice only if they can be implemented effectively without excessive administrative costs. Either a tax or an inflexible cap could meet that criterion.

Administering an "upstream" tax or cap-and-trade program for CO_2 emissions would involve taxing or regulating the suppliers of fossil fuels—such as coal producers, petroleum refiners, and natural gas processors. Compared with a "downstream" design, which would tax or regulate users of fossil fuels, an upstream approach would have two administrative advantages. It would involve regulating a limited number of entities, and it would not require firms to monitor actual emissions. Rather, each firm's tax payment or allowance requirement could be based on the carbon content of its fuel and the amount it sold.[3]

3. For more information about the implications of placing a cap upstream or downstream, see Congressional Budget Office, *An Evaluation of Cap-and-Trade Programs for Reducing U.S. Carbon Emissions* (June 2001).

An upstream tax may be somewhat easier to implement than an upstream cap-and-trade program because many of the entities that would be covered by either policy are already subject to excise taxes.[4] A CO_2 tax could build on that existing structure. Implementing a cap-and-trade program, by contrast, would probably require a new administrative infrastructure. However, the Environmental Protection Agency's experience with the Acid Rain Program (a cap-and-trade program designed to reduce emissions of sulfur dioxide by electricity generators) suggests that the cost of administering such a program could be modest.

Some design features that might improve the efficiency of a cap-and-trade program—such as a price ceiling, banking, and borrowing—could be implemented without unduly increasing administrative costs. A price floor could be relatively easy to implement, but only if the government chose to auction off a significant fraction of the allowances. Other design features could prove more challenging to implement. For example, determining the basis for triggering a circuit breaker (or, more generally, for loosening or tightening the stringency of a cap) would require the government to make judgments about current and future allowance prices.

Comparison of Policies' International Consistency

Carbon dioxide is a global pollutant. A ton of emissions from any point on the globe at any given time would have the same effect on the atmospheric concentration of CO_2 and thus would cause the same amount of damage. Consequently, the most cost-effective way to reach a specific atmospheric concentration would be to undertake the lowest-cost emission reductions regardless of where they were located. Achieving that goal would require creating a uniform incentive to reduce emissions in countries that are major emitters of CO_2.

One option is to have each of the major emitting countries agree to adopt a similar tax on CO_2 emissions. However, a system of harmonized taxes would produce a consistent global incentive for cutting emissions only if participating countries also adopted similar monitoring, verification, and enforcement provisions.

4. For example, coal producers pay an excise tax that is used to fund the Black Lung Trust Fund, and petroleum producers and importers pay an excise tax that finances the Oil Spill Trust Fund.

Alternatively, major emitting nations could agree to link their cap-and-trade programs. In that case, competitive forces would equalize the price of allowances between countries and create consistent incentives to reduce emissions. Uniformity of monitoring and enforcement would be even more important in such an international program. With harmonized taxes, lax monitoring or enforcement by any one country could reduce the incentives for emission reductions in that country. But with linked cap-and-trade programs, laxity in one area could undermine the integrity of allowances throughout the entire system. In addition, linking existing cap-and-trade programs could result in significant flows of capital between countries (from the sale of allowances) and could encourage a nation to set the level of its cap so as to influence those flows.

If the United States included a safety valve or banking or borrowing provisions in its cap-and-trade program, those design features would become available to all sources of CO_2 emissions within a linked cap-and-trade system, regardless of their location. The increased flexibility provided by those design features could undermine the ability of all participating countries to meet a fixed emissions limit in a given year or compliance period; thus, they could be seen as an obstacle to linking with a U.S. cap-and-trade program. For example, if the United States had a cap-and-trade program with a safety valve and linked that program to the European Union's Emission Trading Scheme, which has a fixed cap and no safety valve, countries in the European system would no longer be able to ensure that they could meet the fixed caps they agreed to under the Kyoto Protocol.

Alternatively, any set of policies that resulted in a similar allowance price in different countries would produce efficiency gains similar to those of linking, without requiring nations to give up sovereignty over the price of their allowances or the integrity of their programs. For example, countries with nonlinked cap-and-trade programs could agree to include a safety valve set at a similar level, or the United States could set its safety valve at the same level as a CO_2 tax in another country.

One challenge in crafting an efficient global approach to cutting CO_2 emissions is the inclusion of developing countries that are becoming (or are expected to become) major emitters. China, for example, contributed roughly 8 percent of the world's CO_2 emissions from fossil fuels in 1980, but its share reached 19 percent in 2005. (Dur-

ing the same period, the U.S. share of global emissions fell from 26 percent to 21 percent.[5]) Some researchers suggest that a system of linked cap-and-trade programs could equalize the marginal cost of emission reductions among participating countries while allowing for different levels of reduction among the countries on the basis of fairness or other criteria.[6] Alternatively, some analysts suggest that the revenue generated by taxing CO_2 emissions or selling emission allowances in developed countries could be used to fund emission reductions in developing nations.[7]

Other opportunities also exist for including developing countries. For example, in the European Union's trading program for CO_2 emissions, companies are allowed to comply with some of their allowance requirements by funding emission reductions in developing countries, such as financing a low-emission power plant in China.

5. Department of Energy, Energy Information Administration, *International Energy Annual 2005* (updated September 18, 2007), Table H.1co2, available at www.eia.doe.gov/iea/carbon.html.

6. This point was made by Robert N. Stavins in "Linking Tradable Permit Systems: Opportunities, Challenges, and Implications" (paper presented at the 7th International Emissions Trading Association's Forum on the State of the Greenhouse Gas Market, Washington, D.C., September 27, 2007).

7. See Joseph E. Aldy, Peter R. Orszag, and Joseph E. Stiglitz, "Climate Change: An Agenda for Global Collective Action" (paper prepared for the Pew Center on Global Climate Change's workshop "The Timing of Climate Change Policies," Washington, D.C., October 11–12, 2001); and Joseph E. Aldy, Scott Barrett, and Robert N. Stavins, *13+1: A Comparison of Global Climate Change Policy Architectures*, Discussion Paper 03-26 (Washington, D.C.: Resources for the Future, August 2003).

CHAPTER

1

Efficiency Implications of Different Policy Designs

Incentive-based policies can reduce emissions of carbon dioxide (CO_2) and other greenhouse gases, thereby reducing the risks associated with global climate change, at a lower cost than less flexible alternatives. Policymakers have many options, however, for giving businesses and households an economic incentive to reduce emissions. One option is to regulate the price of emissions—for example, by imposing a tax on them. A tax would limit the cost of cutting emissions but would leave the amount of CO_2 emitted in a given year uncertain. As an alternative, the government could adopt a market-based system to regulate the quantity of emissions—for instance, by combining a cap on total annual emissions with a system of tradable emission permits, or allowances. If monitoring and enforcement were effective, a cap-and-trade program would limit the amount of CO_2 emitted in a given year but would leave the cost of reducing emissions uncertain. The design of a cap could be modified in various ways to make it more flexible and to adopt some of the characteristics of a tax while maintaining the structure of a cap-and-trade program.

Any of those incentive-based approaches could achieve a given cut in emissions at a lower cost than command-and-control approaches, in which the government mandated how much individual factories could emit or what technologies they should use. However, incentive-based approaches would differ in their economic efficiency (the subject of this chapter) and in the ease with which they could be implemented in the United States and coordinated with other countries' emission-reduction policies (discussed in Chapters 2 and 3). The most economically efficient policy is the one that can best keep the marginal cost of reducing emissions—that is, the cost of cutting emissions by another ton—in balance with the marginal benefit (in terms of avoided damage from climate change). A related concept is cost-effectiveness. A cost-effective policy would minimize the cost of meeting a given target for emissions, regardless of whether or not that target was chosen to balance benefits and costs. The efficiency criterion addresses how well policies might function to minimize the cost of reducing emissions over a period of several decades; however, policymakers may choose to place more emphasis on providing certainty about the amount of emissions at specific points in time.

Neither the costs nor the benefits of reducing CO_2 emissions can be known when a reduction policy is put in place. Thus, policymakers must rely on estimates of both of them. The costs of reducing emissions would occur when the reductions were made and could vary substantially depending on such factors as the amount of economic activity, market conditions, weather, and available technologies. The benefits of reducing emissions, in contrast, would be realized decades or even centuries after the reductions were made. The reason is that each ton of CO_2 generates a rise in the average global temperature that peaks about 40 years after the CO_2 is emitted and then dissipates slowly, with a half-life of about 60 years.[1]

Estimating the benefits of cutting emissions is complicated by that long-term effect. In addition, analysts who try to estimate the benefits of cutting emissions face many other challenges, including addressing numerous scientific and economic uncertainties; measuring costs, such as mass species extinction, that are difficult to quantify in economic terms; and deciding how much weight to give to changes in the welfare of future generations.[2]

Some experts think that the effects of climate change could be modest, especially if society is ingenious in adapting to the change. However, other experts are concerned that rising concentrations of greenhouse gases could produce far more severe consequences for the global and U.S. economies than have generally been pro-

1. See William A. Pizer, "Combining Price and Quantity Controls to Mitigate Global Climate Change," *Journal of Public Economics,* vol. 85 (2002), p. 416.

2. For a more detailed discussion, see Congressional Budget Office, *Uncertainty in Analyzing Climate Change: Policy Implications* (January 2005).

jected. Curbing greenhouse-gas emissions would help limit not only the expected costs of future global climate change but also the chances of irreversible or potentially catastrophic damage.

In general, the possibility of significant damage provides an economic motivation for taking additional action to moderate the growth of emissions in the near future—and, potentially, to cut emissions to very low levels in the longer run. Individuals take actions (such as reducing risky behavior or buying insurance) to lessen their harm from extreme events; similarly, societies or governments should and do take actions to avoid catastrophic collective harm. The difficulty for policymakers is determining the appropriate cost to be paid today to lessen what may be a small risk of a potentially catastrophic event in the future.[3]

Although estimating the benefits of emission reductions is difficult, policymakers cannot avoid making a judgment about them: Policy choices about climate change will necessarily imply a value for those benefits. That value would be explicit under a tax, because the tax rate provides an indication of what the government thinks an incremental reduction in emissions is worth. By contrast, that value would be implicit under a cap. A higher (less stringent) cap would imply a lower estimate of the marginal benefit of cutting emissions—as reflected in lower prices for emission allowances—than a lower (more stringent) cap would.

When comparing emission-reduction policies, the Congressional Budget Office (CBO) generally assumes that lawmakers would design them in the most efficient way—that is, to achieve the highest possible net benefits, given the limitations of each particular policy tool. Thus, for example, this analysis compares the most efficient tax on CO_2 with the most efficient cap. In other words, the tax or cap is assumed to be set at a level that encourages the affected parties to reduce emissions as long as the expected cost of doing so is less than or equal to the expected benefit. Those costs and benefits will inevitably be different than anticipated. Policy designs will yield different net benefits depending on their ability to balance the costs and benefits of emission reductions when those turn out to be higher or lower than policymakers had anticipated. Designs that are relatively more efficient would also be relatively cost-effective: The characteristics of a policy design that enable it to equate the cost of additional emission reductions with their anticipated benefits also enable it to minimize the cost of achieving any given emission-reduction target.

3. For more discussion of policy choices in the face of catastrophic costs, see Cass R. Sunstein, *Worst-Case Scenarios* (Cambridge, Mass.: Harvard University Press, 2007).

To be most efficient, a tax would need to rise and a cap would need to decline gradually over time. The future benefits of avoiding climate-change damage by reducing CO_2 emissions by a ton would have an increasingly greater present value (that is, the value today after taking into account the time value of money) as the potential for large damage drew closer in time. An increasingly stringent tax or cap would reflect that increase in present value over time. Further, a gradually rising tax or tightening cap would allow for a smoother transition to a less carbon-intensive economy. Businesses and households would have more time to replace their equipment and energy-use practices with more efficient alternatives.

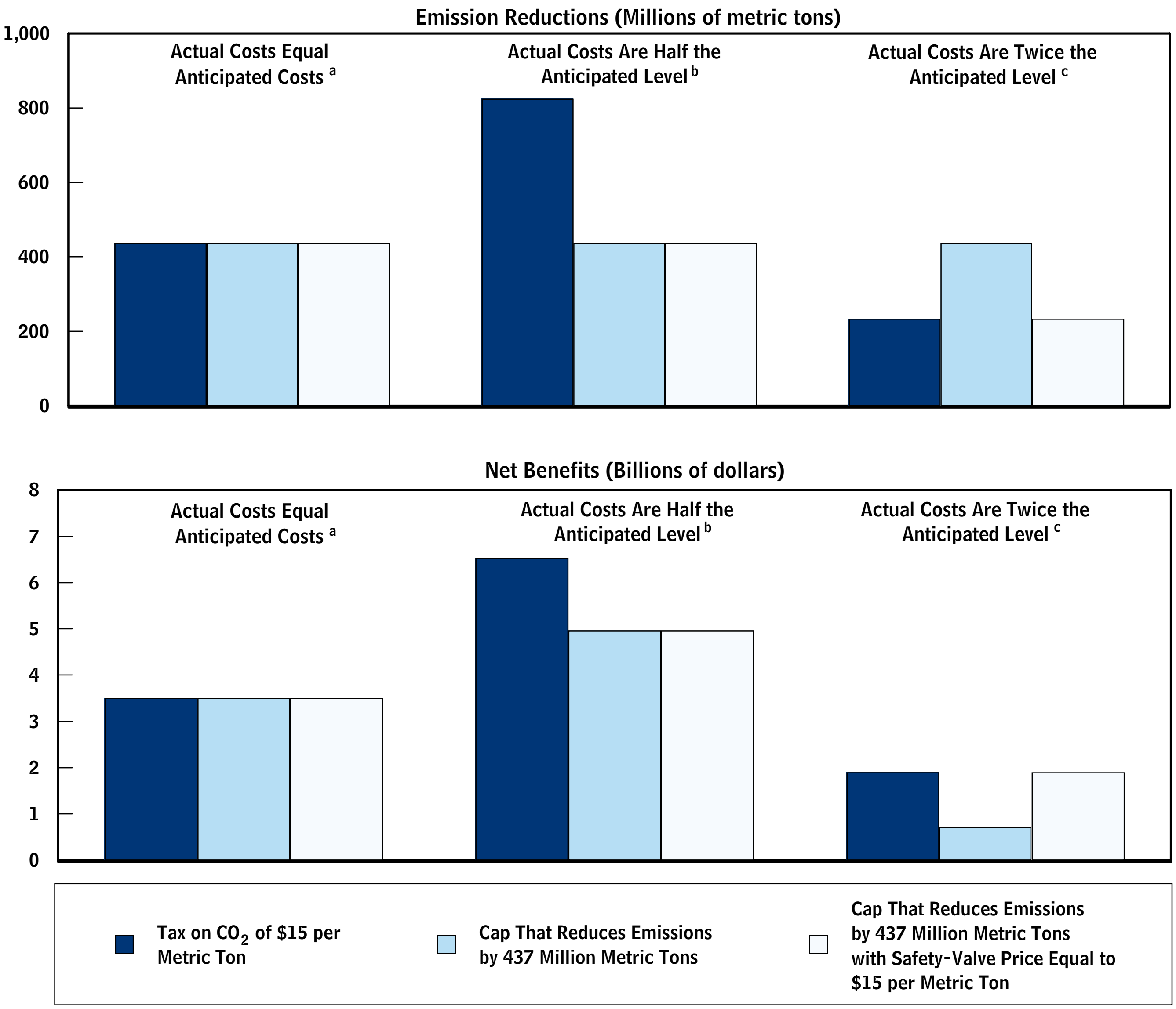
A Carbon Dioxide Tax Versus an Inflexible Carbon Dioxide Cap

According to many analysts, a tax would be a more economically efficient policy for reducing CO_2 emissions than an inflexible cap (with "inflexible" meaning a cap whose level was not affected by the price of emission allowances). That conclusion stems from the cumulative, long-term nature of climate change: The benefit of emitting one less ton of CO_2 in a given year is roughly constant, whereas the cost of emitting one less ton of CO_2 each year rises with each ton reduced. The reason for rising marginal costs is that companies that have to comply with an emission-reduction policy will make the cheapest cuts first and progressively more expensive cuts thereafter.

The contrast between constant marginal benefits and rising marginal costs means that the gap between uncertain costs and benefits is particularly sensitive to the amount of annual emission reductions. A cap that is too tight will disproportionately increase costs over benefits, and a cap that is not tight enough will disproportionately lower costs relative to benefits. A tax, by contrast, will tend to hold the costs of emission reductions in line with the constant (although uncertain) expected benefits, encouraging greater emission reductions when costs are low and allowing more emissions when costs are high.

Figure 1-1.

Illustrative Comparison of Various Policies to Reduce CO_2 Emissions Under Different Cost Conditions



Source: Congressional Budget Office.

Notes: For illustrative purposes only, this example assumes that the benefit of reducing carbon dioxide (CO_2) emissions is $15 per metric ton. It examines the net benefits that would result in the first year of each policy, assuming that the policy covered only the United States and took effect in 2017 after having been announced 10 years earlier. The cost of firms' emission reductions (and the response to various taxes) is derived from Mark Lasky, *The Economic Costs of Reducing Emissions of Greenhouse Gases: A Survey of Economic Models,* Congressional Budget Office Technical Paper No. 2003-03 (May 2003).

A safety valve is a ceiling on the price of emission allowances.

a. Assumes that the actual marginal cost of reducing emissions by 437 million metric tons is $15 per metric ton, the cost that policymakers anticipated when they set the cap.

b. Assumes that the actual marginal cost of reducing emissions by 437 million tons is $7.50 per metric ton but that the tax induces more reductions (up to 824 million tons) at a marginal cost of $15 per metric ton.

c. Assumes that the actual marginal cost of reducing emissions by 437 million tons is $30 per metric ton but that the tax induces fewer reductions (234 million tons instead of 437 million), up to a marginal cost of $15 per metric ton.

An Illustrative Example of How a Tax Would Be More Efficient Than a Cap

To understand how a tax could offer efficiency advantages over a cap, assume that the future benefits of limiting emissions have a present value of $15 per metric ton of CO_2 (or $55 per metric ton of carbon), that those benefits would be constant over the range of potential emission reductions during the initial years of the policy, and that the tax or cap would take effect in the United States in 2017.[4] If the costs of cutting emissions turned out to be as expected, the tax and the cap would be equivalent. But if those costs differed from the government's expectations, a tax would be the more efficient policy.

For example, given the assumptions above, if lawmakers imposed a tax of $15 per metric ton on U.S. emissions of CO_2, and if the costs of limiting emissions equaled expectations, the $15 tax would reduce U.S. emissions in 2017 by 437 million metric tons (see the top panel of Figure 1-1). That amount represents a cut of roughly 6.5 percent from the 6.7 billion metric tons that would otherwise be emitted that year, CBO estimates.[5] Alternatively, lawmakers could set a cap that was 437 million metric tons below the baseline level of U.S. emissions, and if the costs of reducing emissions were what they had expected, the incremental cost of meeting the cap would be $15 per metric ton. Under the illustrative assumption that each ton of emission reductions would produce $15 worth of avoided damage and using information about the cost of emission reductions derived from various models, CBO estimates that either policy would yield net benefits of $3.5 billion in its first year (see the lower panel of Figure 1-1).[6]

If the costs of cutting emissions were different than expected, however—for example, if new technologies turned out to be less expensive than anticipated—the two policies would produce different outcomes.

If the costs of cutting emissions were half the anticipated level—for example, because of unforeseen technological breakthroughs—both policies would produce higher net benefits than expected.[7] The increase in net benefits, though, would be greater under a tax than under a cap: The tax would give firms an incentive to keep cutting emissions as long as doing so cost less than paying the tax. CBO estimates that in this scenario a tax would cause emissions to be cut by 824 million metric tons (roughly 12 percent below the baseline level), rather than by the 437 million metric tons required by the cap. Each of those additional cuts would boost net benefits because they would cost less than, or as much as, their $15 per ton expected benefit.

Alternatively, if the cost of reducing emissions turned out to be twice as high as expected, the net benefits would be lower under each policy—but would fall much more under the cap than under the tax. In particular, under the inflexible cap, firms would be required to reduce emissions by 437 million metric tons, even though reaching that target would entail making reductions that cost up to $30 per metric ton but provided benefits of only $15 per metric ton. As a result of the higher costs, the total net benefits of the cap would fall to $0.7 billion—just one-fifth of the expected amount. A tax would also have lower net benefits if the costs of cutting emissions proved greater than expected. But net benefits would decline by less for a tax than for a cap. Because companies would have the flexibility to reduce emissions by less than 437

4. The stringency of emission-reduction policies is sometimes discussed in terms of carbon and sometimes in terms of CO_2. Estimated costs or benefits that appear in dollars per ton of CO_2 can easily be translated into dollars per ton of carbon by multiplying by the ratio of the molecular weight of CO_2 to the molecular weight of carbon (44/12, or 3.67). Thus, a tax of $15 per ton of CO_2 translates into a tax of $55 per ton of carbon. Conversely, costs and benefits that are stated in terms of dollars per ton of carbon can be converted into dollars per ton of CO_2 by dividing by 3.67.

5. For a description of how CBO calculated the emission reductions that would result from a given tax, or the price of allowances that would result from a given cap, see Mark Lasky, *The Economic Cost of Reducing Emissions of Greenhouse Gases: A Survey of Economic Models,* CBO Technical Paper 2003-03 (May 2003).

6. The cost of reducing emissions in any given year is incurred in that year, while the benefits accrue over a period of decades or centuries. Thus, comparing the costs and benefits of emission reductions involves discounting the value of future benefits to the current year. This illustrative example assumes that the benefits of reducing a ton of emissions have a present value of $15. As a result, reducing emissions by 437 million metric tons would produce benefits of $6.55 billion. The cost of achieving those reductions would be $3.07 billion, according to Lasky, *The Economic Cost of Reducing Emissions of Greenhouse Gases.*

7. The cost changes considered in this example correspond to two separate doublings of the price sensitivity parameter. Thus, the cost of cutting emissions by 437 million metric tons doubles from $7.50 to $15 per metric ton and then from $15 to $30 per metric ton.

million metric tons, the net benefits of a tax would be more than twice those of a cap.

Like costs, benefits could also be higher or lower than anticipated; however, neither policy would adjust to that change. If actual marginal benefits turned out to be much higher than expected, either a tax or a cap would produce too few cuts in emissions, and both policies would fall short of the most efficient level of emission reductions by the same amount.[8]

Empirical Estimates of the Efficiency Advantage of a Tax

If the government wanted to maximize expected net benefits, it would need to set the level of a cap or a tax in a given year on the basis of its best estimate of both the costs and benefits of reducing emissions in that year. However, actual costs in any year are likely to differ from the best estimate, sometimes exceeding it and sometimes falling below it. Because a tax would motivate only emission reductions that cost less than the tax rate, it would automatically adjust the quantity of emission reductions to keep their costs in line with their anticipated benefits, whereas a cap would not.

When analysts take into account the degree to which costs are likely to vary around a single best estimate, they conclude that a tax could offer much higher net benefits than a cap. One study suggests that the net benefits of a worldwide tax on CO_2 emissions in 2010 would be more than eight times larger than those of an equivalent inflexible cap. If the policies are assumed to be set in place for 100 years, the efficiency advantage of a tax declines to a factor of five.[9] Another study concluded that a tax could offer up to 16 times greater expected net benefits than a cap under some assumptions.[10] A third study examined outcomes when cost shocks were assumed to be correlated across time—that is, an unusually high cost of meeting the cap in any given year increases the likelihood of a higher than average cost in the following year. Using their base-case parameter estimates for factors that might affect costs (such as baseline emissions and changes in technology) and assuming a 10-year policy, those researchers estimated that the net benefits of a tax would be roughly five times higher than those of a cap.[11] Taken together, those studies suggest that the net benefits of a tax could be roughly five times those of an inflexible cap (see Figure 1-2)—assuming that both policies were designed to balance expected costs and benefits.

Viewed another way, any long-term emission-reduction target could be met by a tax at a fraction of the cost of an inflexible cap-and-trade program. That cost savings stems from the fact that a tax could better accommodate cost fluctuations while simultaneously achieving a long-term emission target. It would provide firms with an incentive to undertake more emission reductions when the cost of doing so was relatively low and allow them to reduce emissions less when the cost of doing so was particularly high.

The Impact of Price Volatility

The flexibility in reducing emissions that a tax affords is important because the cost of cutting emissions by a given amount could vary from year to year depending on such factors as the weather, the level of economic activity, and the availability of low-carbon technologies. A tax would provide a steady, predictable price for emissions. An inflexible cap, however, could result in volatile allowance prices, making a cap-and-trade program more disruptive to the economy than a tax would be.

Experience with cap-and-trade programs has shown that price volatility can be a major concern when a program's

8. For a more detailed discussion of the uncertainty about the costs and benefits of emission reductions, see Congressional Budget Office, *Uncertainty in Analyzing Climate Change: Policy Implications* (January 2005), pp. 30–31.

9. See Pizer, "Combining Price and Quantity Controls to Mitigate Global Climate Change." That paper considered a worldwide tax or cap on carbon emissions. In analyzing the sensitivity of his results to how long the policies are assumed to remain in place, the author assumed that the damage from climate change would rise rapidly once a certain temperature increase had occurred (in other words, that the damage function was sharply kinked). In that case, a cap would yield larger net benefits than a tax. However, the difference ($600 billion) would be small compared with the net benefits offered by either policy (roughly $34 trillion). Thus, under a sharply kinked damage function, the paramount concern would be to make drastic cuts in emissions, and the choice of policy tool would be relatively unimportant.

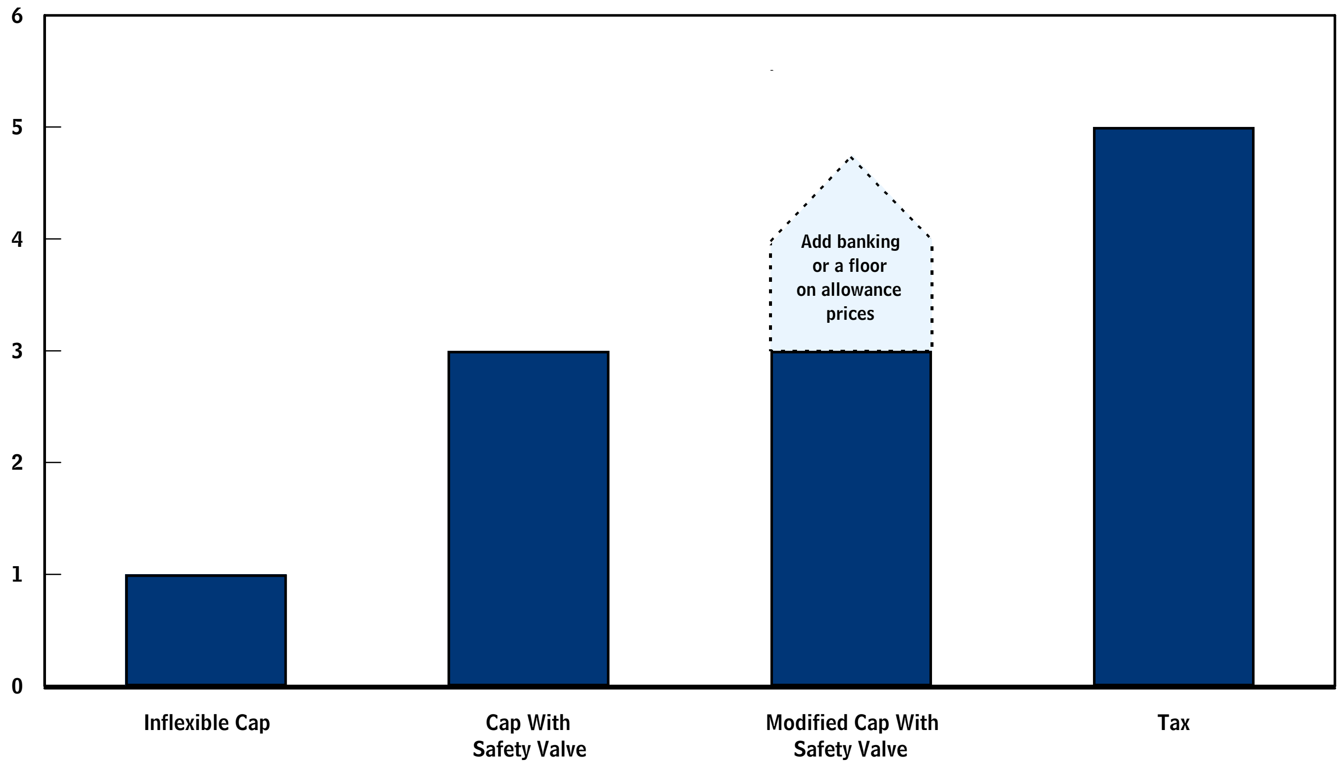
10. Michael Hoel and Larry Karp, "Taxes and Quotas for a Stock Pollutant with Multiplicative Uncertainty," *Journal of Public Economics,* vol. 82 (2001), pp. 91–114. Only under the assumptions of very great damage from climate change and a large initial stock of allowances do those authors conclude that a cap would be more efficient.

11. See Richard G. Newell and William A. Pizer, "Regulating Stock Externalities Under Uncertainty," *Journal of Environmental Economics and Management,* vol. 45 (2002), pp. 416–432.

Figure 1-2.

Relative Economic Efficiency of Various Policies to Reduce CO_2 Emissions, When Cost Uncertainty Is Taken Into Account

(Index, inflexible cap = 1)



Source: Congressional Budget Office based on estimates of the relative magnitude of the net benefits of various policies found in William A. Pizer, "Combining Price and Quantity Controls to Mitigate Global Climate Change," *Journal of Public Economics,* vol. 85 (2002), pp. 409–434, and in Richard G. Newell and William A. Pizer, "Regulating Stock Externalities Under Uncertainty," *Journal of Environmental Economics and Management,* vol. 45 (2002), pp. 416–432.

Notes: The net benefits of each policy are shown in relationship to each other with the net benefits of an inflexible cap set equal to one. The inflexible cap and the tax are assumed to be set at the most efficient level—that is, at the point at which the expected marginal cost of complying with the policy would be equal to the anticipated marginal benefit of reducing emissions.

The net benefits of a cap with a safety valve (a ceiling on the price of emission allowances) are based on the assumption that the cap would be set at the level of the most efficient inflexible cap and the safety-valve price would be set at the level of the most efficient tax. Banking would enable firms to save unused allowances from one period to use in a future period.

The net benefits of a cap-and-trade program with a circuit breaker (not shown in the figure) would be greater than those of an inflexible cap and less than those of a cap with a safety valve; however, CBO lacked sufficient information to determine how much greater or less they would be.

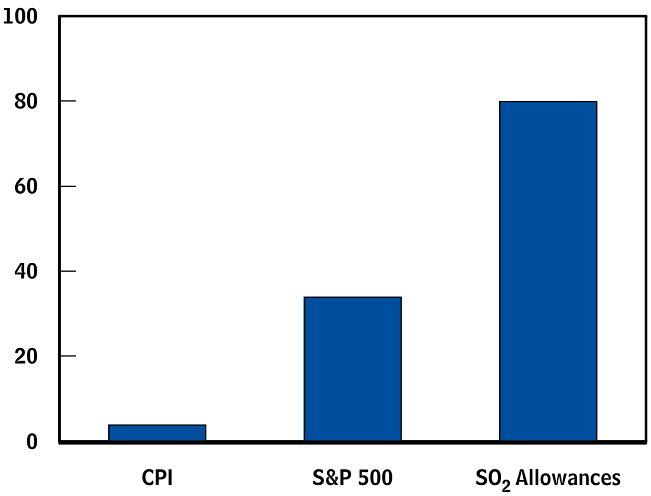
A cap-and-trade program that included a safety valve and either a price floor or banking provisions could be significantly more efficient than an inflexible cap, although somewhat less efficient than a tax.

CO_2 = carbon dioxide.

Figure 1-3.

Volatility of SO_2 Allowance Prices and Selected Other Prices, 1995 to 2006

(Average annual percentage rate of volatility)



Source: Congressional Budget Office based on William D. Nordhaus, "To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming," *Review of Environmental Economics and Policy,* vol. 1, no. 1 (Winter 2007), pp. 26–44.

Note: Volatility is calculated as the annualized absolute logarithmic month-to-month change in the consumer price index (CPI), the stock price index for the Standard & Poor's 500 (S&P 500), and the price of sulphur dioxide (SO_2) allowances under the U.S. Acid Rain Program.

design does not include provisions to adjust for unexpectedly high costs and to prevent price spikes. For example, one researcher found that the price of sulfur dioxide allowances under the U.S. Acid Rain Program was significantly more volatile than stock prices between 1995 and 2006 (see Figure 1-3).[12]

Price volatility was most apparent in the summer of 2000 in Southern California's Regional Clean Air Incentives Market (RECLAIM), a program that capped emissions of nitrous oxide (NO_x) from the power sector. A heat wave caused demand for electricity to soar that summer, while the availability of imported power from other states declined. The increase in demand had to be met by running many of California's old gas-fired generating facilities, which had not yet installed NO_x emission controls. As a result, the demand for NO_x RECLAIM Trading Credits for 2000 rose significantly, boosting their average annual price tenfold (from $4,284 per ton in 1999 to almost $45,000 per ton in 2000) and contributing to high wholesale electricity prices in California during that period.[13] In addition to the California experience, allowance prices in the European Union's (EU's) Emission Trading Scheme (ETS)—a trading program that covers CO_2 emissions from roughly 12,000 sources across 27 countries—fell drastically when it became evident that policymakers had overallocated emission allowances.

Price volatility could be particularly problematic with CO_2 allowances because fossil fuels play such an important role in the U.S. economy. They accounted for 85 percent of the energy consumed in the United States in 2006. CO_2 allowance prices could affect energy prices, inflation rates, and the value of imports and exports. Volatile allowance prices could have disruptive effects on markets for energy and energy-intensive goods and services and make investment planning difficult.[14] The smoother price path offered by a CO_2 tax would better enable firms to plan for investments in capital equipment that would reduce CO_2 emissions (for example, by increasing efficiency or using low-carbon fuels) and could provide a more certain price signal for firms considering investing in the development of new emission-reduction technologies.

Conditions Under Which a Cap Could Be More Efficient Than a Tax

To compare the net benefits of a tax and a cap, researchers must estimate the marginal benefit of reducing a ton of CO_2 emissions. The efficiency advantage of a tax over a cap, however, does not depend on any particular measure of that benefit or even on the ability to place a monetary value on it. Rather, the advantage of a tax stems from the cumulative nature of climate change and from the fact that a tax is better able to reduce emissions over time

12. William D. Nordhaus, "To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming," *Review of Environmental Economics and Policy,* vol. 1, no. 1 (Winter 2007), pp. 26–44.

13. See A. Denny Ellerman, Paul L. Jaskow, and David Harrison Jr., *Emissions Trading in the U.S.: Experience, Lessons, and Considerations for Greenhouse Gases* (Arlington, Va.: Pew Center on Global Climate Change, May 2003), pp. 24–25, available at www.pewclimate.org/global-warming-in-depth/all_reports/emissions_trading. Some observers argue that the lack of banking provisions contributed to the price spikes. Such spikes could have been prevented by the inclusion of a safety valve as well. (Those design features are discussed later in this chapter.)

14. Nordhaus, "To Tax or Not to Tax," pp. 37–39.

without imposing potentially disruptive and unnecessarily expensive annual limits on emissions.

The relative advantages of a tax and a cap could change over time, however. One area of growing concern is that the buildup of greenhouse gases in the atmosphere could cause the global temperature to reach a critical level after which further growth in emissions could trigger a rapid increase in damage.[15] The existence of such a threshold could alter the assumption that the marginal benefit of reducing emissions would be relatively constant and could make a cap more efficient than a tax.

Although concerns about thresholds exist, analysts who have tried to define more precisely the conditions that would cause a cap to be more efficient than a tax have concluded that those conditions are quite narrow and unlikely to apply in the near term. Specifically, scientists would need to have fairly precise knowledge about the location of an emissions threshold, and the threshold would have to be sufficiently close that the government would want to make very large cuts in emissions each year to avoid crossing it.[16] If, instead, policymakers wanted to stabilize the concentration of greenhouse gases in the atmosphere after a period of several decades (at a level that would be expected to prevent the global temperature from rising to a trigger level), there could be considerable leeway about when the reductions took place. A tax would provide flexibility in the timing of emission reductions by encouraging companies to cut emissions more in years when the cost of doing so was low and cutting less when the cost was high. A rigid cap would not provide that flexibility over time.

A fundamental change in the cost of reducing emissions could also reverse the efficiency rankings of a tax and a cap. A cap could become more efficient than a tax if a new technology provided the opportunity to make extremely large cuts in emissions at a low and fairly constant cost, rather than at a rising marginal cost.

15. See National Research Council, *Abrupt Climate Change: Inevitable Surprises* (Washington, D.C.: National Academy Press, 2002), pp. 13–14; R.B. Alley and others, "Abrupt Climate Change," *Science*, vol. 229 (March 28, 2003), pp. 2005–2010; and Congressional Budget Office, *Uncertainty in Analyzing Climate Change*, Box 2-1, pp. 10–11.

16. See William A. Pizer, *Climate Change Catastrophes*, Discussion Paper 03-31 (Washington, D.C.: Resources for the Future, May 2003).

Other Efficiency Implications of a Tax or a Cap

Besides the efficiency advantages described earlier, a tax on CO_2 emissions could offer another advantage. By generating a significant amount of revenue, it would give the government a chance to use the revenue in a way that would lower the cost to the economy of curbing emissions. For example, studies have found that the economy-wide cost of reducing emissions could be more than twice as high if the reduction was achieved through a cap-and-trade program (with allowances allocated for free) than if it was achieved through a CO_2 tax (with the revenue used to reduce existing taxes that discourage economic activity, such as taxes on capital, labor, or income).[17] A cap-and-trade program could offer a similar opportunity, but only if the government chose to sell the allowances rather than give them away.

If the government elected to tax CO_2 emissions or sell allowances for them, it could opt to use some of the revenue to achieve other aims as well. One goal could be to offset the adverse financial impact of a CO_2 tax or cap on low-income households, who would bear a disproportionate burden (relative to their income) from the higher energy prices that the policy would trigger. In addition, lawmakers could compensate workers in carbon-intensive sectors (such as the coal industry) who might lose their jobs because of the policy.[18]

Flexible Cap Designs

A cap on CO_2 emissions could achieve some of the efficiency advantages of a tax while maintaining the basic structure of a cap-and-trade program by incorporating various design features to make the cap more flexible. Such policies would allow the cap to be exceeded or altered depending on economic circumstances that affect the cost of reducing emissions.

A Ceiling or Floor on Allowance Prices

Combining an emissions cap with a ceiling on the price of allowances—or safety valve—could offer some of the advantages of a tax.[19] Under that approach, if the cost of cutting emissions (as indicated by the price of allowances)

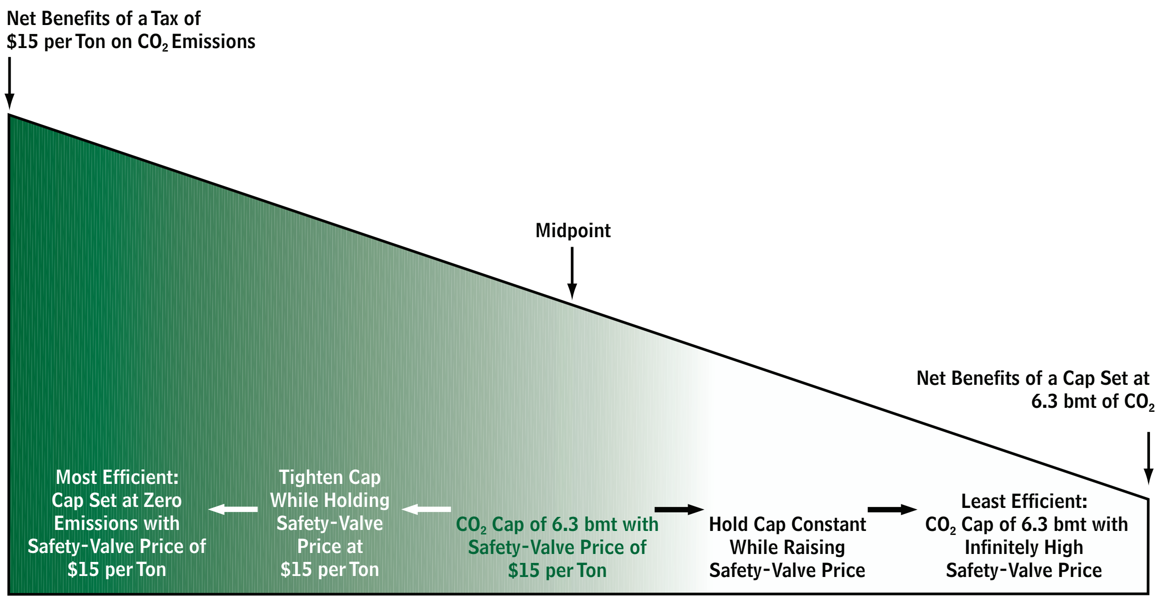
17. See Congressional Budget Office, *Trade-Offs in Allocating Allowances for CO_2 Emissions* (April 25, 2007).

18. Ibid.

19. That feature is included in a cap-and-trade proposal (S. 1766) introduced by Senator Bingaman on July 11, 2007.

Figure 1-4.

Illustrative Range of Net Benefits for a Cap With a Safety Valve Compared With a Tax or an Inflexible Cap on CO_2 Emissions



Source: Congressional Budget Office based on information from Richard G. Newell and William A. Pizer, *Indexed Regulation*, Discussion Paper 06-32 (Washington, D.C.: Resources for the Future, June 2006).

Note: CO_2 = carbon dioxide; bmt = billion metric tons.

rose to the safety-valve level, the government would issue an unlimited number of allowances at that price, thus allowing emissions to exceed the cap. However, unlike a tax, a cap with a safety valve would not give firms and households an incentive to make additional emission cuts if the cost of doing so was lower than anticipated.

In the illustrative example described above, if a cap limiting CO_2 emissions to 6.3 billion metric tons in 2017 (437 million tons below the baseline level for that year) included a safety-valve price of $15 per metric ton of carbon, it would produce the same outcome as a tax of $15 per ton if the cost of meeting the cap was higher than expected (see Figure 1-1 on page 3). In that case, both the tax and the cap/safety valve policy would allow higher emissions than an inflexible cap and would limit the cost of reductions to $15 per ton. Conversely, if the cost of meeting the cap was lower than expected, the cap/safety valve would produce the same outcome as an inflexible cap. The lower-than-expected costs would cause net benefits to be higher than anticipated, but not as high as they would be with a tax.

Under some circumstances, a cap with a safety valve could offer roughly half of the efficiency gains of a tax over a rigid cap. That situation would be most likely to occur if the safety-valve price was set at the amount of the most efficient tax (assumed to be $15 per ton of CO_2 in this example) and the cap was set at the level of the most efficient inflexible cap (estimated to be 6.3 billion metric tons, on the basis of an assumed marginal benefit of $15 per ton of CO_2 and the quantity of emission reductions that would result from that price).[20] In that case, the net benefits of the cap/safety valve policy would fall roughly halfway between those of a cap and a tax (see Figure 1-2 on page 6).

If the safety-valve price was kept at the level of the most efficient tax but the cap was tightened, then the cap/safety valve policy would function more like a tax and would become even more efficient (see Figure 1-4). Specifically, the amount of emission reductions would increasingly depend on the cost limit specified by the

20. As determined in Lasky, *The Economic Cost of Reducing Emissions of Greenhouse Gases*.

safety-valve price rather than on the quantity limit specified by the cap. At the extreme, a cap of zero emissions with a safety-valve price of $15 per ton of CO_2 would provide the same incentives as a tax of $15 per ton. The cap of zero emissions would not prohibit emissions, but companies would have to purchase an allowance from the government at the safety-valve price for each ton of CO_2 they emitted. (Adding banking or a price floor to a cap-and-trade program with a safety valve offers another way to capture more of the efficiency advantages that could result from an appropriately designed tax. That option is discussed later in this chapter.)

In the other direction, if the cap in the cap/safety valve approach remained at the level of the most efficient inflexible cap but the safety-valve price rose above the level of the most efficient tax, then the cap/safety valve policy would function more like an inflexible cap and would become less efficient. In that case, the amount of emission reductions would be more likely to be determined by the cap than by the safety-valve price. At the extreme, if the safety-valve price was raised high enough that the safety valve would not be triggered, the policy would be equivalent to not having a safety valve, and the net benefits would be the same as those of an inflexible cap.

A recent criticism of a safety valve is that it could unintentionally reduce firms' incentives to replace carbon-intensive capital equipment and to develop new technologies for lowering CO_2 emissions.[21] Either taxing or capping emissions would set a price on them. Researchers generally conclude that the most efficient price for CO_2 emissions would be relatively low in the near term but would rise substantially over time. Expectations of higher future prices would give companies an incentive to gradually replace their stock of physical capital associated with carbon-intensive energy use (such as coal-fired generators or inefficient heating systems) and to invest in researching and developing new technologies that would reduce emissions (such as improvements in solar power, wind power, or energy efficiency).[22] The higher that future allowance prices were expected to rise, the greater that incentive would be. Including a safety valve in a cap-and-trade program, however, would lower expectations about future prices by ensuring that the price of allowances would not rise above the safety-valve level, although it could fall below. In other words, the fact that the range of potential future prices would be truncated at the high end by the safety valve but not at the low end would reduce the expected price.[23] As a result, the safety valve could have the unintended effect of inducing less capital-stock turnover and less investment in research and development (R&D) than would occur under an inflexible cap or a tax.[24]

That problem could be addressed by adding a floor on allowance prices.[25] Enforcing a minimum price for allowances could be fairly straightforward if the government chose to sell a significant share of the allowances rather than give them to affected businesses for free. If allowances were auctioned, policymakers could specify a reserve auction price and restrict the supply of allowances to maintain that price. In combination, a reserve price and a safety valve could define a band of acceptable clearing prices for the allowance market in a cap-and-trade system and could stabilize price expectations. Thus, that combined policy could capture much of the efficiency advantage offered by a tax on emissions (see Figure 1-2 on page 6).[26]

21. See Dallas Burtraw and Karen Palmer, "Dynamic Adjustment to Incentive Based Policy to Improve Efficiency and Performance" (draft, Resources for the Future, Washington, D.C., November 30, 2006).

22. The amount of investment in research and development under either a tax or a cap-and-trade program could be less than the amount that would be best for society because such investment may generate "spillover benefits" to society that do not translate into profits for the firm doing the investing. For a discussion of that issue, see Congressional Budget Office, *Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions* (September 2006).

23. For example, suppose policymakers set a cap on emissions in 2020, and observers generally agreed that there was a 25 percent chance that the allowance price necessary to meet the cap would be $25, a 50 percent chance that it would be $50, and a 25 percent chance that it would be $75. With no safety valve, the expected allowance price would be $50 [that is, (0.25 x $25) + (0.50 x $50) + (0.25 x $75)]. If, however, policymakers set a safety valve at $50, the expected allowance price would fall to $43.75 [(0.25 x $25) + (0.75 x $50)].

24. That effect is not reflected in Figure 1-4.

25. Burtraw and Palmer, "Dynamic Adjustment to Incentive Based Policy to Improve Efficiency and Performance."

26. If both the price floor and the safety valve were set at the expected marginal benefit of emission reductions, the combined policy would be analogous to a tax.

Enforcing a minimum price would be considerably more difficult if nearly all of the allowances were given away for free. In that case, the government could attempt to enforce a minimum price only by reducing the supply of allowances—for example, it could buy back allowances from firms or decrease the value of allowances so that each allowance would permit less than one ton of emissions. Determining when such actions should be undertaken would require the government to make judgments about current and future allowance prices (for example, distinguishing short-term dips from long-term trends). To the extent that those judgments were incorrect, the adjustments to the supply of allowances might undercorrect or overcorrect the allowance price. Further, some analysts are concerned that identifying a trigger price at which policymakers would alter the cap could actually promote price volatility. For example, firms might resist buying allowances once the price began to approach or exceed the trigger point, waiting for policymakers to loosen the cap. But once the demand for allowances dropped, the price would begin to fall and the possibility of intervention would diminish. As a result, purchases (and prices) would once again begin to increase.[27]

Alternatively, increasing the stringency of the cap, while holding the safety valve constant, would reduce the potential problem of underinvestment in R&D and insufficient capital-stock turnover. As noted above, the safety valve would become increasingly likely to determine the quantity of emission reductions and the price of allowances. It would also keep the amount of reductions from falling below the efficient level when the cost of cutting emissions was low. Another option that could help address the underinvestment problem would be to allow emitters to bank allowances for future use.

Banking and Borrowing Allowances

Banking and borrowing would give firms the opportunity to move allowances—and the emissions that correspond to them—between time periods. Each emission allowance would be valid for a specific year or alternative compliance period. (A 2017 allowance, for example, would allow the company that held it to emit one ton of emissions in that year.) With banking, a company could reduce its emissions below the amount it would be permitted to emit on the basis of its allowance holdings for a given year, thereby using fewer allowances in that year, and could bank the extra allowances to use in a future year.[28] With borrowing, by contrast, a firm could exceed its permitted level of emissions in one year by borrowing from its allocation of allowances for a future year.

Emitters would want to bank allowances in years when they thought the price of allowances was low relative to that of future years (for example, because of a mild winter or a period of slow economic activity, or because they believed that tighter caps in the future would lead to higher allowance prices). Conversely, companies would want to borrow allowances in years when they thought the price of allowances was high relative to that of future years (for example, because they expected a new, low-cost technology for reducing emissions to become available later).

Banking Allowances. Banking provisions could improve the efficiency of a cap-and-trade program, regardless of whether the program included a safety valve. While a safety valve could prevent the price of allowances from climbing too high, banking could help prevent the price from falling lower than policymakers would like. Firms would have an incentive to bank allowances in a given year if the cost of making *additional* emission reductions in the current year—that is, reductions in excess of the aggregate amount that firms need for compliance in that year—was less than the expected present value of the cost of reducing emissions or buying allowances in the future. By providing firms with an incentive to save their own allowances—or purchase additional allowances for saving—banking would boost the demand for, and the price of, allowances in years in which that price was relatively low.[29]

The combination of banking and a safety valve could help keep the marginal cost of emission reductions in line with their anticipated benefits under some conditions. For example, such a policy could be effective in preventing relatively short-term lows in allowance prices, but it

27. See Ian W.H. Parry and William A. Pizer, "Emissions Trading Versus CO_2 Taxes Versus Standards," in Raymond J. Kopp and William A. Pizer, eds., *Assessing U.S. Climate Policy Options: A Report Summarizing the Work at RFF as Part of the Inter-Industry U.S. Climate Policy Forum* (Washington, D.C.: Resources for the Future, November 2007), pp. 83–84.

28. Uncertainty about the existence of a cap-and-trade program in the future would undermine incentives for banking.

29. See Henry D. Jacoby and A. Denny Ellerman, "The Safety Valve and Climate Policy," *Energy Policy,* vol. 32, no. 4 (March 2004), pp. 481–491.

would be less effective in boosting the price of allowances if the cost of reducing emissions turned out to be significantly lower than anticipated in both the near term and the long term—because of the introduction of a new technology, for instance.[30] In that case, the market price for allowances could stay well below the safety-valve price (that is, below the expected marginal benefits), and the policy would motivate too few emission reductions. As discussed above, policymakers could help ensure that the safety valve would be triggered by setting the cap relatively tightly in comparison with the safety-valve price (see Figure 1-4).

Provided that the safety valve was expected to be eliminated at some point, combining a safety valve with banking provisions could create an incentive for firms to purchase very large amounts of allowances through the safety-valve mechanism and bank them for use once the safety valve was removed.[31] That strategy could prevent a sharp increase in the price of allowances once the safety valve was removed, but it could also mean that the cap would not be met for several years after the removal. The potential for such an outcome would be greatest if the safety valve was holding the price of allowances well below the actual cost of meeting the cap. For example, suppose that firms were allowed to buy allowances through the safety valve in 2020 for $20 but that the safety valve was expected to be removed in 2021 and that, in its absence, the price of allowances required to actually meet the 2021 cap was anticipated to be $40. In that case, firms would have an incentive to purchase very large quantities of allowances through the safety valve in 2020 and use those allowances once the safety valve was removed.

The large excess supply of allowances purchased through the safety valve would prevent the steep jump in allowance prices that would have occurred if firms had not been allowed to bank allowances, but it would also mean that the annual cap in 2021—and for a period of time thereafter—would not be met, even though the safety valve was no longer in place. If policymakers wished to reduce the potential for a multiyear delay in attaining the cap after the safety valve was removed, they could require firms to use allowances purchased at the safety-valve price in the year in which they were purchased.[32]

In addition, policymakers could choose to sell safety-valve allowances through an auction—rather than at a given price—and specify a reserve price for the auction that would increase as greater quantities of allowances were sold in any given year. For example, policymakers could choose to auction blocks of allowances, with increasing reserve prices, just prior to each year's compliance deadline. The reserve price could be $22 for the first block, for instance, $24 for the second block, and so on. Such a strategy could prevent the price of allowances from jumping up once the safety valve was removed while limiting firms' incentives to bank a large supply of allowances for use in future years.[33]

Borrowing Allowances. Including either borrowing provisions or a safety valve in a cap-and-trade program could help prevent spikes in the price of allowances; however, a safety valve could offer greater efficiency advantages. Borrowing would help bring down the price of allowances in a given year only if the price in that year was high relative to prices anticipated in future years. For example, if the price of allowances was $30 in 2010 and was expected to be $15 in 2015, then a firm would have an incentive to borrow 2015 allowances for use in 2010. If, however, the price was expected to be $45 in 2015, no such incentive would exist. Thus, borrowing could help avoid a price spike but would not necessarily keep the cost of emission reductions from exceeding their expected benefits. A safety valve, in contrast, could prevent the cost of emission reductions from exceeding estimates of the benefit of those reductions.

30. For a discussion of this point, see Burtraw and Palmer, "Dynamic Adjustment to Incentive Based Policy to Improve Efficiency and Performance."

31. This observation was made by William A. Pizer of Resources for the Future in a personal communication to the Congressional Budget Office.

32. That requirement would reduce, but not eliminate, the delay. Firms would be able to comply in 2020 by using safety-valve allowances and then banking 2020 allowances that they had obtained by other means (such as receiving for free, making reductions, or purchasing from other firms).

33. This suggestion was offered by William A. Pizer of Resources for the Future.

Allowing firms to make one-for-one trades between current and future allowances (and, correspondingly, between current and future emissions) would provide them with too much incentive to defer emission reductions to the future. Because firms discount future costs relative to current costs, they would have an incentive to engage in borrowing (and, thus, defer the cost of reducing emissions) simply to delay the cost of reducing emissions. The potential for excessive borrowing could be avoided if the government discounted borrowed allowances at the rate that companies use to discount future costs.[34] That rate will generally vary from firm to firm; however, policymakers would need to choose a single discount rate. Some researchers suggest that the government could use a discount rate equal to the industry average interest rate used to finance medium-term capital expenditures.[35] In addition, policymakers could choose to limit the amount of borrowed allowances that companies might use for compliance in any given period or the length of time over which borrowing might occur.

Policymakers could attempt to enforce a ceiling on the price of allowances (for example, keeping it roughly in line with the expected benefits of reducing emissions) by altering the terms under which firms could borrow allowances.[36] Reducing restrictions on borrowing or lowering the rate at which borrowed allowances were discounted could increase the supply of borrowed allowances and thus reduce allowance prices in the near term. As described above, such a strategy could only be effective if firms anticipated that the price of emission reductions in the future would be low (in present-value terms) relative to the current price of allowances. (If that was not the case, firms would not have an incentive to borrow, even under the revised terms.) As a result, altering the terms under which firms might borrow allowances would be more effective in dealing with relatively short-term price spikes than with a situation in which policymakers had underestimated the cost of compliance—in both the near term and in the future—when they set the level of the cap.

Using such a strategy to enforce a limit on the price of allowances would require policymakers to have relatively accurate information about both the current and future prices of allowances. To the extent that those estimates were wrong, the changes that policymakers made to borrowing terms could over- or undercorrect the price. For example, if policymakers reduced restrictions on borrowing in order to lower the current price of allowances, but market conditions changed, the increased supply of allowances could cause their price to drop more than policymakers had intended. Alternatively, the increased availability of allowances might fail to reduce the current price as much as policymakers had anticipated.

Circuit Breaker

Some analysts have suggested that an emissions cap that declined at a preset rate and that included a "circuit breaker" would offer economic advantages relative to an inflexible cap and perhaps relative to a cap with a safety valve as well. The circuit breaker would freeze the cap if the price of an allowance exceeded a specified level.[37]

Provided that the circuit breaker price was set at an efficient level (that is, the level that reflected the best available information on costs and benefits), a cap-and-trade program with a circuit breaker could be more efficient than a rigid cap. Specifically, it would offer some economic relief if the cost of meeting the declining cap was higher than the anticipated marginal benefits. Unlike a safety valve, however, a circuit breaker would not set an upper limit on the cost of reducing emissions. Once the circuit breaker was triggered and the cap stopped declining, the allowance price could continue to increase (albeit by not as much as if the circuit breaker was absent). In fact, continued price increases would be likely because meeting a constant cap would become increasingly costly as the economy grew. Thus, assuming that the circuit breaker price was set equal to the expected marginal benefits of reducing emissions, the allowance price (and the cost of achieving additional emission reductions) would be likely to rise above those expected benefits.

34. If each allowance let firms emit one ton of CO_2, a borrowed allowance could permit a firm to emit less than one ton, with the amount of the reduction depending on the discount rate that policymakers chose and the number of years in the future from which the reduction was borrowed. Alternatively, policymakers could allow firms to emit one ton of emissions for each borrowed allowance but could require that they reduce emissions by more than one ton when they pay back the allowance loan.

35. See Catherine Kling and Jonathan Rubin, "Bankable Permits for the Control of Environmental Pollution," *Journal of Public Economics,* vol. 64, no. 1 (April 1997), p. 112.

36. For example, that feature is included in the cap-and-trade proposal (S. 2191) introduced by Senators Lieberman and Warner on October 18, 2007.

37. See the statement of Joel Bluestein before the Subcommittee on Clean Air, Climate Change, and Nuclear Safety of the Senate Committee on Environment and Public Works, May 8, 2003.

CHAPTER

2

Implementation Considerations for Different Policy Designs

In addition to the efficiency trade-offs highlighted in the previous chapter, policymakers may wish to weigh other aspects of alternative policies, including the likelihood that the policy could be easily implemented. The following discussion examines the relative ease of implementing a carbon dioxide tax, an inflexible cap, and the flexible cap designs discussed in the previous chapter. It is not meant to provide a comprehensive examination of the challenges associated with implementing individual policies but rather to highlight implementation considerations that would vary across policies.

A Carbon Dioxide Tax Versus an Inflexible Carbon Dioxide Cap

Successfully implementing either a CO_2 tax or an inflexible cap would entail several similar requirements. Under an upstream design, suppliers of fossil fuels (such as coal producers, petroleum refiners, and natural gas processors) would be required to pay a tax—or hold an allowance—for each ton of carbon that was contained in the fuel they sold (and, thus, would be emitted in the form of CO_2 when the fuel was burned). In that case, firms would need to report their sales data and the carbon content of the fuels they sold so that regulators could determine each firm's tax or allowance requirement. Regulators would need to have methods of verifying the accuracy of the reported data. In that way, they could detect underpayments of taxes or excessive emissions and impose adequate, consistent, and predictable penalties.

Further, regulators would need to have a method of ensuring that all fuels that should be subject to the regulatory requirements were covered by the policy. That would entail accounting for fossil fuels that did not pass through a domestic mine mouth (less than 0.5 percent of all coal consumed in the United States), a domestic petroleum refinery (approximately 1 percent of the petroleum produced or imported into the United States), or a natural gas processing plant (approximately 22 percent of the natural gas consumed in the United States).[1] Finally, regulators would need to be able to accurately identify fossil fuels that were not combusted and, therefore, should be exempt from the tax or allowance requirement, such as petroleum that was used in producing plastics or tires. On the basis of information from the Energy Information Administration, such a system would entail regulating roughly 150 oil refineries, 1,460 coal mines, and 530 natural gas processing plants.[2]

Moving the point of regulation downstream—to users of fossil fuels—could be more difficult to implement in some sectors. For the power sector, such a change would be relatively simple to make because large power producers subject to the Acid Rain Program are required under the Clean Air Act to have equipment in place that continuously monitors CO_2 emissions. (See the appendix for a description of the Acid Rain Program.) Outside the power sector, however, a downstream system could impose significant implementation challenges. The number of entities that would need to be regulated would grow, and identifying their emissions would initially be difficult. In fact, inaccurate data about the baseline emissions of downstream industries (such as cement, iron, and steel plants) in the European Union's trading program

1. Based on information provided to the Congressional Budget Office by the Environmental Protection Agency's Clean Air Markets Division (July 5, 2007).

2. See Department of Energy, Energy Information Administration, "EIA-820, Annual Refinery Report" as of January 1, 2006, and "EIA-816, Monthly Natural Gas Liquids Report," both available at www.eia.doe.gov/oss/forms.html, and EIA's 2005 Coal Production Data Files, available at www.eia.doe.gov/cneaf/coal/page/database.html.

for CO_2 emissions caused regulators to issue more allowances to those industries than they intended to under the first phase of the program. That overallocation contributed to large price swings at the end of the first year of reporting.[3]

Similar data problems occurred with the start-up of the Acid Rain Program. It took the Environmental Protection Agency two rounds of data review with industry (through public notice and comment) over the course of two years to sort out anomalies in the data used for determining generating units' initial allocations (based on energy data reported to the Department of Energy). For example, EPA made adjustments for electricity generating units that had significant outages during the period that was used to determine the initial allocations. Because EPA had a much longer time to implement the Acid Rain Program than the EU had to implement the initial phase of its program for carbon dioxide, EPA was able to review and revise the data before allocating the allowances. And because the anomalies were discovered before the initial allocations were made and the trading program was operational, the revisions did not lead to price swings in the allowance market.[4]

Another implementation consideration is whether allowances should be grandfathered, or given away for free, on the basis of previously existing circumstances. A cap-and-trade program in which allowances were not grandfathered could have substantially lower start-up costs (because it would avoid the lengthy process of determining the basis for grandfathering) than a cap-and-trade program in which allowances were grandfathered. A tax would have significantly lower start-up costs than a cap-and-trade program with grandfathering provided that policymakers did not decide to grant exemptions based on historical production or emissions data. Further, implementing a tax would not require the government to set up a process for auctioning allowances.

3. Once this fact was revealed, prices of allowances fell by more than 75 percent. See the statement of Jill Duggan, Head of International Emissions Trading, U.K. Department for Environment, Food, and Rural Affairs, *EU Cap-and-Trade Programme,* before the House Committee on Energy and Commerce (March 29, 2007), p. 3.

4. Based on information provided to the Congressional Budget Office by the Environmental Protection Agency's Clean Air Markets Division (July 5, 2007) as well as Joseph Kruger and William A. Pizer, *The EU Emissions Trading Directive: Opportunities and Potential Pitfalls* (Washington, D.C.: Resources for the Future, April 2004), pp. 14–15.

The cost of implementing an upstream carbon tax is likely to be less than that of a cap-and-trade program (regardless of how allowances were initially allocated) because the tax could build upon an existing infrastructure. For example, coal producers already pay an excise tax (which is used to fund the Black Lung Trust Fund) as do producers and importers of petroleum (to fund the Oil Spill Trust Fund). A CO_2 tax based on the sales of coal or petroleum would be an additional excise tax and could, presumably, be implemented at a relatively modest incremental cost. While natural gas is not subject to a federal excise tax, many natural gas processors are subject to a corporate income tax.

In contrast, implementing an upstream cap-and-trade program would probably require a new administrative infrastructure. However, based on EPA's experience with the Acid Rain Program, the cost of administering such a program could be relatively modest. Regulators would need to take the following steps:

- Set up an allowance account for each regulated unit and for other nonregulated entities that might wish to trade allowances (such as brokers),
- Record information on allowance allocations for each regulated unit,
- Review submitted allowance transfers to make sure that they have all necessary information and meet the regulatory requirements,
- Record transfers into and out of each account, and
- Notify both participants in a transfer when the transfer was recorded.[5]

EPA estimates that it spends approximately $1.5 million annually to operate its Allowance Tracking and Allowance Transfer Systems for the Acid Rain Program.[6] That program maintains accounts for regulated power generators (who must comply with the cap-and-trade program) as well as for other traders. On the basis of the most recent data, a little more than half of the accounts

5. Those steps are based on EPA's responsibilities for operating both the Allowance Tracking System and the Allowance Transfer System for sulfur dioxide trading under the Acid Rain Program. See Environmental Protection Agency, *Information Collection Request Renewal for the Acid Rain Program Under the Clean Air Act Amendments Title IV* (July 26, 2006), pp. 31–32.

6. Ibid., p. 32.

(roughly 1,200) are held by regulated generators, and the remainder (915) are general accounts.[7] In 2005, nearly 5,700 private allowance transfers (moving roughly 20 million allowances) were recorded in EPA's Allowance Tracking System.[8]

Flexible Cap Designs

As discussed in the previous chapter, including features in a cap-and-trade program that would make it more responsive to annual variations in the cost of reducing emissions could improve its efficiency. In some cases, those features could be relatively easy to incorporate:

- Implementing a safety valve (a ceiling on the price of emission allowances) could be relatively straightforward. The government could offer an unlimited amount of allowances at the safety-valve price.

- Implementing banking provisions (in which firms could save allowances from one period to use in a future period) could also be straightforward. Banking has already been successfully implemented in several existing cap-and-trade systems. For example, emitters in the Acid Rain Program may bank allowances for an unlimited amount of time, and some countries participating in the European Union's Emission Trading Scheme allowed banking in the first phase of the program (2005 to 2007). For implementation purposes, borrowing (in which firms use allowances designated for a future period in the current period) would be similar to banking.

Other features of a cap-and-trade program could be more difficult to implement. A circuit breaker, which would freeze an otherwise declining cap once the price of allowances rose to a predetermined circuit-breaker price (and would keep the cap at that level until the allowance price fell back below the circuit-breaker price) could pose more significant implementation challenges. In order to determine when to trigger the circuit breaker, policymakers would need accurate information on allowance prices. They would also need to decide how sensitive the trigger would be. For example, would the circuit breaker be triggered if any single allowance was traded at a price above the circuit-breaker price? Or would it be based on a price index? If so, would the chosen price indicator have to remain above the circuit-breaker price for a given amount of time? Making such determinations could be difficult, for several reasons:

- Allowances for CO_2 could be traded in "over the counter" transactions between an individual buyer and seller (possibly through a broker)—as is the case for the sulfur dioxide (SO_2) allowances that are traded under the Acid Rain Program. In such transactions, the parties involved are not required to report the price at which the commodity is traded. In the case of SO_2, most brokers voluntarily report prices, and several publications report prices or publish indexes—but those prices are not verified.[9]

- Traders could have an incentive to provide inaccurate information about prices. For example, sellers of allowances could inflate their price information to convince buyers that they need to pay more for their allowances. Likewise, regulated entities might wish to have the price of allowances appear high enough to trigger the circuit breaker so as to prevent the CO_2 cap from becoming more stringent.

- Prices could fluctuate widely over time. Determining whether a change in price represented a temporary spike or a more permanent shift in underlying market conditions would be difficult.

- There could be several different prices for allowances at any given point, and those prices would vary during a year. As a result, determining when the circuit breaker should be triggered could be difficult: Policymakers would need to decide which allowance price the circuit breaker would be based on and how long that price would have to be above the specified level to cause the cap to stop declining. Policymakers would need to make similar decisions in order to determine when the circuit breaker should no longer be in effect—and the cap should once again begin to decline.

7. Based on information provided to the Congressional Budget Office by the Environmental Protection Agency's Clean Air Markets Division (July 5, 2007).

8. See Environmental Protection Agency, *Acid Rain 2005 Progress Report,* EPA-430-R-06-15 (October 2006), p. 9.

9. Based on information provided to the Congressional Budget Office by the Environmental Protection Agency's Clean Air Markets Division (July 5, 2007).

CHAPTER

3

International Consistency Considerations for Different Policy Designs

Carbon dioxide is a global pollutant: A ton of emissions from any point on the globe (at a given time) would have the same effect on the atmospheric concentration of CO_2 and, therefore, would result in the same amount of damage. As a consequence, the most cost-effective method of achieving a given atmospheric concentration of CO_2 would be to undertake the lowest-cost emission reductions, regardless of where those opportunities were located. Achieving that goal would require that major emitting countries coordinate their policies to create a consistent economic incentive to reduce emissions. Choices that U.S. policymakers might make could affect the feasibility of creating such an incentive.

As in the previous chapter, this discussion is not meant to provide a comprehensive examination of the challenges in coordinating policies with other countries but rather to highlight how the ability to achieve that goal might vary across the policy designs. For example, effective government institutions and legal systems in each country would be necessary to successfully implement any type of multinational tax or cap-and-trade program and, therefore, would not give one policy a comparative advantage over another. Further, this discussion focuses primarily on the efficiency implications of creating a consistent economic incentive to reduce emissions in major emitting countries and touches only briefly on the potential equity issues associated with achieving that goal.

A Carbon Dioxide Tax Versus an Inflexible Carbon Dioxide Cap

Major emitting countries could achieve a uniform price on CO_2 by agreeing to implement the same tax on emissions (that is, to harmonize their countries' policies). Alternatively, each country could establish a national cap-and-trade program and agree to link their programs by permitting allowance trading across borders. In that case, competitive forces would lead to a single allowance price.

Harmonizing a U.S. Tax on CO_2 With Policies in Other Countries

A direct method of achieving a uniform price on CO_2 across multiple countries would be for each country to adopt the same tax. For example, each country might agree upon a specific tax rate, such as $15 per metric ton of CO_2. (That tax rate was used as an illustrative example in Chapter 1.) A uniform tax rate would ensure an equal level of incentive to reduce emissions in participating countries only if the following conditions were met:

- Participating countries had equally effective monitoring and enforcement provisions. Less effective monitoring, lower penalties, or less rigorous enforcement in any given country would reduce the economic incentive provided by its tax and would be equivalent to reducing the country's tax rate.[1]

- Participating countries agreed on similar tax exemptions or other special provisions. For example, if one country provided an exemption for the steel industry, that industry would have a reduced incentive to cut its

1. In addition, countries would need to be prevented from changing their tax codes in order to neutralize the effect of the carbon tax. See Joseph E. Aldy, Scott Barrett, and Robert N. Stavins, *13+1: A Comparison of Global Climate Change Policy Architectures,* Discussion Paper 03-26 (Washington, D.C.: Resources for the Future, August 2003), p. 13. For a discussion of some potential methods of inducing international compliance—such as using economic sanctions, social sanctions, "carrots," or other indirect incentives—see Joseph E. Aldy, Peter R. Orszag, and Joseph E. Stiglitz, "Climate Change: An Agenda for Global Collective Action" (paper prepared for the Pew Center on Global Climate Change's workshop "The Timing of Climate Change Policies," Washington, D.C., October 11–12, 2001).

emissions and would have a competitive advantage over steel industries in other countries with the same tax but no exemption.

- Participating countries implemented the tax at the same point in the carbon supply chain or made special provisions for differences in the point of implementation. For example, a country with an upstream tax on fossil fuel suppliers would need to exempt fossil fuels that were sold to a country with a downstream tax on fossil fuel users in order to avoid double-taxing emissions.

Alternatively, the United States could choose to implement a CO_2 tax set at a rate to be consistent with the price of CO_2 in an outside cap-and-trade system, such as the European Union's Emission Trading Scheme (see the appendix). Such a tax could only roughly approximate the allowance price because allowance prices are difficult to predict and can fluctuate widely over time.[2] Further, attempts to harmonize the CO_2 tax rate in the United States with the allowance price in an outside trading program would have to take into account differences in the point of implementation. For example, if the United States adopted an upstream tax, it would need to exempt any fossil fuels that were sold to countries participating in the EU's ETS, because that system regulates emissions at the point of combustion.

Linking a U.S. Cap-and-Trade Program With Outside Cap-and-Trade Programs

Linking the cap-and-trade programs of multiple countries to achieve a uniform price of CO_2 would involve the same complications associated with harmonizing tax rates. As with a tax, participating countries would need similar monitoring of emissions, tracking of allowance transactions, penalties for noncompliance, and enforcement provisions. In contrast with a harmonized tax, lax monitoring or enforcement in one country would undermine the effectiveness of the policy not only in that country but in other participating countries as well. The country with lax enforcement could become a supplier of fraudulent allowances (ones that did not correspond to actual reductions), diminishing the environmental integrity of the entire trading system.[3] Further, the systems that track and transfer allowances in different countries (referred to as "registries" in the EU) would need to be able to communicate with each other.[4] Finally, as with a harmonized tax, each country's cap-and-trade program would need to cover similar sources of emissions, and provisions would need to be made to avoid double-charging (or not charging for) emissions if countries applied their caps at different points in the carbon supply chain.

Linking cap-and-trade programs would also entail additional challenges beyond those associated with harmonizing a tax on CO_2. Linking would change the price of allowances in each participating country, which would alter gains and losses and could create incentives for strategic behavior. A country with a relatively high allowance price (because of a more stringent cap, for example, or a greater dependence on high-carbon fuels) would experience a price decrease as a result of linking. In contrast, a country with a relatively low price before linking would see an increase. Those price changes would have several effects that countries would need to consider:

- The change in the price of allowances would alter the gains and losses experienced by companies that, before linking, had been net buyers or net sellers of allowances. For example, if the United States experienced an increase in the price of allowances as a result of linking, U.S. firms that had been net sellers could benefit, whereas net buyers could be worse off.

- In addition to altering the gains and losses experienced by individual firms, linking would create net flows of allowances—and flows of resulting revenues—into, or out of, countries. Countries could have an incentive to choose their caps strategically so as to take advantage of those potential flows. For example, a country might

2. Prices depend on numerous factors, including the stringency of the cap, available technologies, supply and demand conditions in energy markets, and monitoring and enforcement provisions.

3. See Richard Baron and Stephen Bygrave, *Towards International Emissions Trading: Design Implications for Linkages* (Paris: Organisation for Economic Co-Operation and Development and International Energy Agency, October 2002), p. 21.

4. See Joseph A. Kruger and William A. Pizer, "Greenhouse Gas Trading in Europe: The New Grand Policy Experiment," *Environment*, vol. 46, no. 8 (October 2004), p. 15.

try to choose a less stringent cap so that it could become a net supplier of allowances.[5]

- A change in the price of allowances as a result of linking could alter the incentive of domestic producers to invest in new technologies—such as energy efficiency improvements or alternative fuels—that would reduce CO_2 emissions.

Linking would remove a country's ability to determine the terms of regulation for its own businesses. For example, if a country that did not allow its firms to borrow future allowances for current use was to link with a country that did, firms in both countries would have access to borrowed allowances. In a similar manner, the use of other flexible design features—such as banking, offsets, and a safety valve (discussed in the next section)—would be available to all firms in a linked system should any one country allow its firms to comply in those ways.

Flexible Cap Designs

Design features that could make a U.S. cap-and-trade program more efficient than an inflexible cap could make other countries more or less willing to link their cap-and-trade program with a U.S. program. The following discussion examines linkage considerations associated with efficiency-improving design features discussed in the previous chapter: a safety valve, a price floor, banking and borrowing provisions, and a circuit breaker. It does not address other design features that could influence whether a country decides to link its trading system with a U.S. system. Those features might include U.S. decisions about how to allocate allowances to domestic sources or decisions about whether to allow sources to comply by using offsets such as biological sequestration (capturing carbon for long-term storage in trees or soil), geological sequestration (capturing carbon and storing it in the ocean or in the earth), and projects designed to reduce emissions in developing countries.[6]

Including a safety valve in a U.S. cap-and-trade program could limit the likelihood that countries participating in a system with an inflexible cap, such as the EU's ETS, would be willing to link with a U.S. program. That reluctance could stem from two concerns. First, if the EU agreed to link with a U.S. program, it would no longer be able to maintain a rigid cap because EU sources would have access to allowances at the safety-valve price.[7] In addition, the U.S. government could receive significant revenue by selling allowances to EU firms.

Linking a U.S. cap-and-trade program with trading programs in other countries could limit the ability of the U.S. government to set a floor on the price of allowances, even if it chose to sell a significant fraction of domestic allowances in an auction. Linking could greatly expand the size of the allowance market, which, in turn, would lessen the government's ability to affect their price by withholding allowances from the domestic auction.

As with a safety valve, if one country in a multinational cap-and-trade program chose to allow its emitters to bank or borrow allowances, then those options could become available to all emitters within the system, regardless of their location. For example, if firms in one country were allowed to bank allowances (for example, in 2010), those additional allowances would be available through the allowance trading market to firms in all countries in the linked trading system in a future year (for example, in 2015). Banking could be problematic if some countries had binding targets that had to be met within a given period, however. That concern has caused EU countries to prevent emitters from banking allowances from the first phase (2005 to 2007) of its ETS for use in the second phase, which has binding targets for the 2008–2012 period.[8]

5. See Jane Ellis and Dennis Tirpak, *Linking GHG Emission Trading Schemes and Markets* (Paris: Organisation for Economic Co-Operation and Development and International Energy Agency, October 2006), p. 24; and Erik Haites, "Harmonisation Between National and International Tradeable Permit Schemes: CATEP Synthesis Paper," in *Greenhouse Gas Emissions Trading and Project-Based Mechanisms* (Paris: Organisation for Economic Co-operation and Development's Global Forum on Sustainable Development, Emissions Trading CATEP Country Forum, March 17–18, 2003), p. 107.

6. For a discussion of the implications of those design features for linking, see Ellis and Tirpak, *Linking GHG Emission Trading Schemes and Markets;* and Kruger and Pizer, "Greenhouse Gas Trading in Europe."

7. See Ellis and Tirpak, *Linking GHG Emission Trading Schemes and Markets,* p. 26. Even if EU firms were prohibited from purchasing U.S. allowances through the safety-valve mechanism, U.S. entities could serve as intermediaries: They could purchase safety-valve allowances for their own use, freeing up other allowances to sell to firms in the European Union.

8. Ibid., p. 23.

One of the challenges in designing an efficient global approach to reducing CO_2 emissions is how to include developing countries. Those countries have contributed a small fraction of global emissions in the past, but they are expected to become major contributors in the future. Some researchers suggest that linking a system of fixed cap-and-trade programs could offer an opportunity to equalize the marginal cost of emission reductions among participating countries while allowing for a differentiated level of effort among countries (that is, some countries could be required to make larger emission reductions than others) based on fairness or other criteria.[9] Other researchers suggest that the revenue generated by taxing CO_2 emissions—or by selling allowances—in developed countries could be used to fund emission reductions in developing countries.[10]

9. This point was made by Robert N. Stavins in "Linking Tradable Permit Systems: Opportunities, Challenges, and Implications" (paper presented at the 7th International Emissions Trading Association's Forum on the State of the Greenhouse Gas Market, Washington, D.C., September 27, 2007).

10. See Aldy, Orszag, and Stiglitz, "Climate Change: An Agenda for Global Collective Action"; and Aldy, Barrett, and Stavins, *13+1: A Comparison of Global Climate Change Policy Architectures*.

APPENDIX

A

Current and Proposed Cap-and-Trade Programs in the United States and Europe

The concept of distributing tradable pollution rights—what this paper refers to as emission allowances—first appeared in the academic literature in 1968.[1] Trading programs can be attractive alternatives to more traditional approaches that mandate specific pollution limits for all sources. A primary advantage of trading programs is that they can lower the costs of achieving a given environmental goal by giving participants some flexibility about where and how reductions are made.

Trading programs have been used for various purposes in the United States, such as to decrease the amount of lead in gasoline, to reduce discharges into rivers and reservoirs, and to lower emissions of two air pollutants—sulfur dioxide (SO_2) and nitrous oxide (NO_x). The trading programs for SO_2 and NO_x provide the most relevant comparison for a trading program for carbon dioxide (CO_2) emissions. Trading programs to reduce such emissions have been proposed in the United States and are in effect in Europe.

U.S. Programs for Sulfur Dioxide and Nitrous Oxide

The United States has two major emissions cap-and-trade programs that cover multiple states.[2] The Acid Rain Program is a nationwide program that caps SO_2 emissions from large electric power units. The program took effect in 1995 and was expanded to cover additional units in 2000. It currently covers about 3,000 generating units at more than 700 power plants. The initial free allocation of allowances was based on each unit's fuel input in the mid-1980s, multiplied by an emissions performance standard. Units were allocated 30 years' worth of allowances, and those allowances could be banked indefinitely, meaning that an allowance for a ton of emissions in any given year could be used in that year or in any future year.

The Acid Rain Program is run by the Environmental Protection Agency (EPA) and is widely viewed as being very successful, bringing about large reductions in SO_2 emissions for lower-than-expected costs. Banking provisions contributed to the program's cost-effectiveness, but the free allocation of allowances did not. The method of allocating allowances would have a substantial impact on the distribution of policy costs but, in general, would not affect the overall cost of achieving a cap. (An exception is that free allocations to regulated utilities could increase the cost of achieving a cap by preventing price increases that are essential for triggering cost-effective emission

1. See J.H. Dales, *Pollution, Property, and Prices* (Toronto: University of Toronto Press, 1968). Also see David W. Montgomery, "Markets in Licenses and Efficient Pollution Control Programs," *Journal of Economic Theory,* vol. 5 (1972); and Tom H. Tietenberg, *Emissions Trading: An Exercise in Reforming Pollution Policy* (Washington, D.C.: Resources for the Future, 1985).

2. For a summary of these programs, see Joseph A. Kruger and William A. Pizer, "Greenhouse Gas Trading in Europe: The New Grand Policy Experiment," *Environment,* vol. 46, no. 8 (October 2004), p. 14. For more detailed descriptions of the multistate trading programs for sulfur dioxide and nitrous oxide, see the "Clean Air Markets" section of the Environmental Protection Agency's Web site, available at www.epa.gov/airmarkets (with links to "Acid Rain Program" and "NOx Trading Programs"). For a detailed description of those programs as well as the Regional Clean Air Incentives Market program, see A. Denny Ellerman, Paul L. Joskow, and David Harrison Jr., *Emissions Trading in the U.S.: Experience, Lessons, and Considerations for Greenhouse Gases* (Arlington, Va.: Pew Center on Global Climate Change, May 2003), available at www.pewclimate.org/global-warming-in-depth/all_reports/emissions_trading.

reductions.) Further, giving allowances to firms, as opposed to selling them, could preclude the government from using the proceeds from selling allowances to reduce existing taxes that dampen economic activity.[3]

The NO_x Budget Trading Program is a multistate trading program that caps nitrous oxide emissions from large industrial boilers and electricity generating units in 19 states, the District of Columbia, and portions of two additional states. That program, which originally encompassed nine northeastern states in the late 1990s, is a partnership between the federal government and state governments. States have responsibility for allocating emission allowances; the EPA implements an emissions and allowance registry, verifies emissions data, runs the trading program, and reconciles emissions and allowances (to determine compliance) at the end of each year. As under the SO_2 trading program, the NO_x allowances are bankable.

In addition to those multistate programs, the South Coast Air Quality Management District, a local air pollution agency in southern California, has operated the Regional Clean Air Incentives Market (RECLAIM) since 1994. That program caps SO_2 and NO_x emissions from various sectors (including the power sector and some industrial sectors). Unlike the Acid Rain and NO_x Budget Trading programs, no banking is allowed under RECLAIM because of concern that banking would lead to unacceptably high emissions in a future year. The lack of banking is thought to have contributed to a severe price spike for NO_x emission rights in California in 2000 (see Chapter 1).

3. For a discussion of the distributional and efficiency aspects of alternatives for allocating allowances, see Congressional Budget Office, *Trade-Offs in Allocating Allowances for CO_2 Emissions* (April 2007).

U.S. and European Programs for Greenhouse Gases

No mandatory cap-and-trade programs for greenhouse-gas emissions such as carbon dioxide currently exist in the United States, but state-level efforts to develop them are under way. For example, 10 states—Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont—are developing a multistate cap-and-trade program covering greenhouse-gas emissions, the Regional Greenhouse Gas Initiative (RGGI). RGGI will begin capping emissions in 2009 and will initially cover CO_2 emissions from power plants in participating states. In the future, RGGI may be extended to include other sources of CO_2 emissions and other greenhouse gases.[4]

Further, the state of California is actively considering the feasibility of implementing a cap-and-trade program for CO_2 emissions. In September 2006, California enacted legislation that directs the California Air Resources Board (CARB) to establish a comprehensive program that would reduce the state's greenhouse-gas emissions to 1990 levels by 2020.[5] The legislation does not specifically require the use of a market-based system, such as a cap-and-trade program, but instructs CARB to consider other proposed or existing trading programs, including RGGI.

The largest cap-and-trade program for CO_2 emissions at present is the European Union's Emission Trading Scheme (ETS). The initial phase of the ETS—the warm-up phase—went into effect in 2005 and continued through 2007. The second phase, which is in effect from 2008 through 2012, coincides with the initial phase of the Kyoto Protocol. The ETS currently covers carbon

4. For more information, see the Regional Greenhouse Gas Initiative's Web site at www.rggi.org.

5. See Jonathan Ramseur, *Climate Change: Action by States to Address Greenhouse Gas Emissions,* CRS Report for Congress RL33812 (Congressional Research Service, January 18, 2007).

dioxide emissions from roughly 12,000 sources across the 27 countries of the European Union. Sources of covered emissions include factories that produce iron and steel, cement, glass and ceramics, pulp and paper, electric power, and petroleum products. Other greenhouse gases and other sectors, such as aviation, may be added in the future. Allowances valued at $23 billion and covering more than 1 billion metric tons of emissions were traded in the EU's ETS in 2006.

The warm-up phase of the ETS provides several lessons for avoiding potential problems in the future. For example, observers of the program note that member states had insufficient historic emissions data for some participating installations. As a result, some member states based their allocations of allowances on estimates rather than actual emissions. The resulting inaccuracies led to caps that were less stringent than anticipated, and the market price for allowances dropped significantly when that overallocation became apparent.[6]

6. See Kruger and Pizer, "Greenhouse Gas Trading in Europe"; and Senate Committee on Energy and Natural Resources, "Full Committee Roundtable: European Union's Emissions Trading Scheme" (March 26, 2007), available at http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=1615. In addition, the United Kingdom initiated a voluntary emissions-trading system in 2002. Thirty-three organizations adopted emission-reduction targets to reduce their emissions against 1998–2000 levels. That trading scheme ended in December 2006. See "UK Emissions Trading Scheme" at www.defra.gov.uk/environment/climatechange/trading/uk/index.htm.